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Multi-trajectory analysis of concurrent changes in physical activity and body mass index among 66,852 public sector employees over 16-year follow-up

Running head: **Trajectories of physical activity and BMI**

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DECLARATIONS

Ethics approval and consent to participate:

The ethics committee of the Hospital District of Helsinki and Uusimaa approved the study (registration number HUS/1210/2016). Consent to participate was obtained from each participant.

Consent for publication:

Not applicable

Availability of data and materials:

We are allowed to share anonymised questionnaire data of the Finnish Public Sector Study by application for with bona fide researchers with an established scientific record and bona fide organisations. For information about the Finnish Public Sector Study contact Prof. Mika Kivimaki mika.kivimaki[at]helsinki.fi / Dr. Jenni Ervasti jenni.ervasti[at]ttl.fi.

Competing interests:

The authors declare that they have no competing interests.

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Author contributions

All the authors (RT, MS, JE, MK, JP, SS, JV) substantially contributed to the conception and design of the work, the interpretation of the results and revising it critically for important intellectual content. JE, JV and MK were responsible for the acquisition of data for the work. MS and JP were responsible for the statistical analysis. RT and MS were responsible for drafting the work. All the authors (RT,

MS, JE, MK, JP, SS, JV) have finally approved the version to be published and they are agreed to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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None to declare

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Study importance

What is already known about this subject: Physical activity decreases and BMI increases with advancing age when studied separately.

What this study adds: Physical activity and BMI are interconnected and there is a negative association between physical activity and BMI. In this study, four clusters of BMI and physical activity trajectories were indentified.

ABSTRACT

Background

Physical inactivity and body weight tend to increase with age, but their concurrent changes across life is less studied. The objective was to identify concurrent developmental trajectories of physical activity and Body Mass Index (BMI) over 16 years.

Methods

66,852 participants from the Finnish Public Sector cohort study were included. Physical activity during leisure time and commuting and self-reported BMI were assessed with questionnaires. Participants were divided into two age groups; ≤50 and >50 years at baseline. Group-based multi-trajectory modeling was used to investigate the clusters of concurrent BMI and physical activity trajectories over 16 years. For sensitivity analysis, the respondents were stratified by gender.

Results

At baseline, mean age was 44.7 (SD 9.4) years, BMI 25.1 (SD 4.1) kg/m^2 and physical activity 27.7 (SD 24.8) MET-h/week. Four clusters of concurrent BMI and physical activity trajectories were identified in both age groups. Overall, there was negative association between BMI and physical activity at baseline with BMI increasing and physical activity decreasing over time. The decline in physical activity and increase in BMI were steeper among the respondents with obesity or severe obesity, who had moderately low or low level of physical activity.

Conclusions

Changes in BMI and physical activity were interconnected.

Keywords

"Physical activity"; "Body Mass Index"; "Population Dynamics"[Mesh]; "Population Characteristics"[Mesh]; "Population Health"[Mesh]; ("Prevalence"[Mesh]); "Longitudinal Studies"[Mesh]

Strengths and limitations of this study

- Long follow-up of 16 years
- Large sample size of 66,852 participants
- Repeated measurements of physical activity and BMI
- Only leisure-time physical activity was taken into account, leaving out work-related activity
- BMI and physical activity were self-reported, which may cause bias

INTRODUCTION

Both obesity and physical inactivity have negative impact on multiple aspects of health and they increase the risk of mortality [1-3]. Ageing is associated with gaining weight and decreasing physical activity [4-6], but less is known whether these changes occur simultaneously and how much heterogeneity there is in the developmental trajectories of body weight and physical activity.

Few studies have examined heterogeneity in weight development over time more closely. A study amongst 30-year-old US war veterans identified five different, but all increasing, trajectories of body mass index (BMI) over 6-year follow-up [6]. However, the steepness of trajectories varied: while the non-obese participants showed only a small increase in BMI, the increase was much steeper among the participants with obesity. Another study from the US conducted on 60-year-old overweight participants identified seven weight trajectories of which most showed either stable overweight, continuously increasing BMI or relapse after weight loss. Even in the two trajectory groups showing decrease in BMI the participants remained overweight.[7].

Physical activity has also been reported to change over time. Leisure time physical activity among women has previously been reported to increase until age of 50 years and start to decrease after that.[4] For men, the change in leisure time physical activity has been reported to vary between different types of activity - while moderate physical activity increased, low and high levels decreased.[5] Studies concerning trajectories of physical activity have found variation in development of activity. A 22-year follow-up study from Canada among initially 18 to 60 year-olds has identified trajectories of consistently inactive, increasing, consistently active and decreasing leisure time physical activity.[8] Another study conducted in the US among 120 initially overweight people aged 54 (±9) years has measured activity with pedometers and identified ”sedentary” and ”low active” groups (decreasing daily count of steps), ”somewhat active” group (persistent daily count of steps) and ”active” group (increased daily count of steps) in 18-month follow-up.[9]

The association between higher levels of physical activity and lower BMI has been established in adults [10 11], and there has been some evidence that this association might be most pronounced

when physical activity exceeds 150 min/week.[10] There is, however, limited knowledge on simultaneous changes in these two factors. In short-term follow-up (18 months) among overweight 54-year-old Canadians, a trajectory with increasing activity has been associated with a trajectory of greater weight loss.[9] There is yet little knowledge on these two factors over longer follow-up. It is also unknown whether developmental patterns of BMI and physical activity differ by age or by gender.

To address the gap in the literature, the objective of this study was to examine concurrent changes in BMI and physical activity over 16-year follow-up by using a group-based multi-trajectory analysis. While conventional statistics show a trajectory of average change of outcome over time, group-based trajectory modeling can distinguish and describe subpopulations (clusters), which may differ substantially from each other and from the average trajectory seen in the entire population. The aim was also to examine, whether the distinguished trajectories are different for less than 50-year-olds and over 50-year-olds and whether the results are different when the study population is stratified by gender.

METHODS

Study population

Participants were drawn from the Finnish Public Sector (FPS) cohort study of employees of 10 towns and six hospital districts. Data included responses to five questionnaire surveys administered to the FPS sub-cohorts in four-year intervals from 2000 to 2017 (average response rate 70%). The baseline was the response given in 2000 or 2004. Participants who had reported their BMI and physical activity in at least two waves were included in the analysis. The ethics committee of the Hospital District of Helsinki and Uusimaa approved the study (registration number HUS/1210/2016).

Physical activity was assessed with a questionnaire at all four-year intervals. The respondents were asked to estimate their average weekly hours of leisure-time physical activity/exercise and commuting activity within the previous year. The time spent on activity at each intensity level in hours per week was multiplied by the average energy expenditure of each activity, expressed in metabolic equivalent of task (MET). [12] The MET is a ratio of rate of energy expenditure reflecting the amount of consumed energy compared to resting. One MET unit of 3.5 ml of oxygen per kg per minute corresponds to oxygen consumption when calmly sitting down.

The BMI was defined as weight/height^2 (kg/m^2) based on self-reported body weight and height. The interpretation of the mean level of BMI trajectories was based on the following categorization: normal weight (<25 kg/m^2), overweight (25 to 29.9 kg/m^2), obese (30-34.9 kg/m^2) and severely obese (≥35 kg/m^2). Of the respondents, only 934 (1%) had BMI ≤18.5, and thus, for the matter of clarity, BMI <25 was considered “normal”. Age was defined in full years.

Statistical analysis

The characteristics of participants were reported as means and standard deviations or as absolute numbers and percentage when appropriate.

Group-based multi-trajectory analysis (GBTA) was used to distinguish different developmental trajectories for physical activity and BMI, both treated as continuous variables. A censored (known also as 'regular') normal model of group-based multi-trajectory analysis was used. The goodness of model fit was judged by running the procedure several times with a number of subpopulations starting from one up to six. The Bayesian Information Criterion (BIC), Akaike information criterion (AIC) and average posterior probability (APP) were used as criteria to confirm the goodness of fit. A cubic regression was applied. The cut-off for the smallest group was set at ≥5%. The trajectory analysis was conducted on two age-groups ≤50 and >50 years as previous studies have suggested that changes in BMI and physical activity may vary depending on the age [13 14]. The sensitivity analysis was conducted by dividing both age groups by gender.

All the analyses were performed using Stata/IC Statistical Software: Release 16. College Station (StataCorp LP, TX, USA). The additional Stata module 'traj' was required to conduct group-based trajectory analysis. The module is freely available for both SAS® and Stata software (Jones and Nagin 1999; 2013).

Patient and public involvement

Participants of research were not involved in setting the study question and outcome measures and were not involved in the design and implementation of the study or writing the manuscript.

RESULTS

During the 16-year follow-up, the 66,852 participants had reported body weight and height on average in 3.5 (SD 1.3) study waves and physical activity in 3.6 (SD 1.3) study waves. The sample was predominated by 53,468 women (80%). In the younger group (≤ 50-year-olds) mean age was 39.8 (SD 7.2), BMI at baseline was 24.6 (SD 4.0) kg/m^2 and average physical activity was 28.8. (SD 25.5) MET-h/week. In the older group (>50-year-olds), age was 55.0 (SD 2.9), BMI 25.6 (SD 4.2) kg/m^2 and physical activity 26.7 (SD 24.1) MET-h/week.

A four-trajectory model was chosen as the five-trajectory model had resulted in a smallest group below a pre-agreed cut-off of 5% (Table 1). Four concurrent trajectories of BMI and physical activity were identified for both age groups (Figure 1 and Figure 2):

1. Group 1 (38% among < 50 years, 32% among ≥ 50 years): Individuals with normal weight (BMI <25 kg/m^2) and high level of physical activity (30-35 MET-h).
2. Group 2 (39% among < 50 years, 42% among ≥ 50 years): Individuals with overweight (BMI 25 to 30 kg/m^2) and moderately high level of physical activity (25-30 MET-h).
3. Group 3 (18% among < 50 years, 21% among ≥ 50 years): Individuals with obesity (BMI 30 to 35 kg/m^2) and moderately low level of physical activity (20-25 MET-h).
4. Group 4 (5% among < 50 years, 5% among ≥ 50 years): Individuals with severe obesity (BMI >35 kg/m^2) and low level of physical activity (<20 MET-h).

Group 1: Individuals with normal weight and high level of physical activity

In this group, the younger respondents demonstrated a stable high level of physical activity with a slight rise towards the end of follow-up and their BMI increased slightly throughout the follow-up. For the older respondents, the level of physical activity decreased markedly during the follow-up, even if there was a slight rising pattern in the middle of follow-up. At the same time, the trajectory of BMI remained flat.

Group 2: Individuals with overweight and moderately high level of physical activity

In this group, the level of physical activity declined in both age groups, but the decline was steeper among the older respondents. In younger respondents, the decrease of physical activity slowed down slightly towards the end of follow-up. Simultaneously, BMI was steadily growing among younger respondents, while remaining relatively flat in older group.

Group 3: Individuals with obesity and moderately low level of physical activity

The physical activity and BMI trajectories were similar to the trajectories observed in group of overweight individuals with moderately high level of physical activity (group #2), but with a slightly steeper decline in physical activity and steeper increase in BMI.

Group 4: Individuals with severe obesity and low level of physical activity

Also in this group, physical activity decreased and BMI increased. In younger respondents, this development slowed down at the end follow-up for both physical activity and BMI. Instead, in older respondents, the decrease in physical activity accelerated towards the end of follow-up with simultaneous slight decline in BMI.

Sensitivity analysis

Stratifying the respondents by gender in addition to age resulted in similar findings with few exceptions (supplementary figures E1-E4). Among normal weight or overweight respondents, the decline in physical activity was steeper among men compared to women.

DISCUSSION

This prospective cohort study in 66,852 public sector employees followed repeatedly by 4-year intervals investigated trajectories of concurrent changes in BMI and physical activity over 16 years. Four trajectory clusters were identified for both participants aged ≤50 and for those >50 years: 1) individuals with normal weight and high level of physical activity; 2) individuals with overweight and moderately high level of physical activity; 3) individuals with obesity and moderately low level of physical activity; and 4) individuals with severe obesity and low level of physical activity. On average, BMI increased and physical activity decreased during the follow-up. Some trajectories demonstrated, however, distinctive features. Over time, the respondents with normal weight or overweight gained only a little weight while preserved a high or moderately high level of physical activity, even if the intensity of physical activity mildly decreased especially in older respondents. The decrease in physical activity and increase in BMI were steeper among the respondents with obesity or severe obesity, who had moderately low or low level of physical activity already at the start of the follow-up. Among the normal weight or overweight respondents, decline in physical activity was steeper among men compared to women.

The observed age-related weight gain is in line with previous studies [4-6 15], as well as the decline in physical activity [4 16 17]. Previous studies have also shown that an increase in BMI slows down with advancing age, and this was also supported by the present findings – the rise in BMI was steeper in the younger respondents [18 19]. During the follow-up, the decline in physical activity mirrored the increase in BMI. Similar findings have been reported before – several studies conducted among middle-aged adults have observed an association between physical activity and weight gain [10 11 20 21]. This association has been described to be dose-dependent – physically active individuals gain less weight than inactive peers. [11] Current results support this finding, since the increase in BMI was less steep in the more active groups. The amount of activity needed to prevent weight gain has been debated. Some studies have concluded that current activity recommendations are not sufficient enough to prevent weight gain and that there is a need for higher activity to remain in the normally

weighted category [10 11 20]. This is in line with the current findings – only high physical activity was associated with normal weight.

The strengths of the study were long follow-up of 16 years, repeated measurements on physical activity and BMI, and a large sample size. For our knowledge, there are no previous multi-trajectory analyses of the relation between physical activity and BMI conducted in adults.

The study has also some limitations. Physical activity was self-reported and only leisure-time and commuting activity were inquired. Thus, physical activity at work was not considered. The distribution of physical activity intensity was skewed – most of the participants were at least somewhat active, and even in the least active group the mean activity level was approximately 18 MET/week. BMI was also based on self-reported weight and height, which may cause recall and information bias, possibly resulting in under-reporting of body weight [22]. Most of the participants had BMI above 25 indicating overweight or obesity (62% in the age group of ≤50 years and 68% in the older), which may reflect the current overweight and obesity pandemic. The cohort included predominantly working-age women employed in public sector. Therefore, the results might not be directly reflected on the entire population, since there might be variation in behavior, for instance among unemployed people or entrepreneurs. Moreover, a public sector often employs people with higher socioeconomic status, who might have more knowledge and financial resources to healthy lifestyle choices compared to manual workers.

Conclusions

Changes in BMI and physical activity were interconnected. The normal weight or overweight respondents gained only a little weight while preserved a high or moderately high level of physical activity. Compared to normal weight trajectories, the decrease of physical activity and increase in BMI were markedly steeper among the obese or severely obese trajectories, who also had moderately low or low level of physical activity. Among the normal weight and overweight trajectories, decline in physical activity was steeper among men compared to women. Since physical inactivity and

overweight are both risk factors for many diseases, more research is needed to develop interventions that could simultaneously affect both.

LIST OF ABBREVIATIONS

BMI: Body Mass Index

FPS: Finnish Public Sector cohort study

MET: Metabolic Equivalent of Task

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TABLES

Table 1. Goodness of fit of group-based trajectory analysis models. The chosen models are shown in bold.

Model	Smallest group		BIC[1]	AIC[2]	APP[3]
	n	%			
<51 years					
1-cluster	31,797	100%	-905,561	-905,509	1
2-cluster	8,234	26%	-869,531	-869,432	0.94
3-cluster	3,331	10%	-851,542	-851,397	0.92
4-cluster	**1,490**	**5%**	**-841,703**	**-841,510**	**0.89**
5-cluster	898	3%	-835,396	-835,157	0.87
>50 years					
1-cluster	35,055	100%	-869,200	-869,148	1
2-cluster	9,690	28%	-836,174	-836,076	0.93
3-cluster	3,845	11%	-819,600	-819,454	0.91
4-cluster	**1,888**	**5%**	**-809,601**	**-809,409**	**0.89**
5-cluster	999	3%	-803,977	-803,738	0.87

[1] BIC = Bayesian Information Criterion, [2] AIC = Akaike information criterion, [3] APP = Smallest average posterior probability

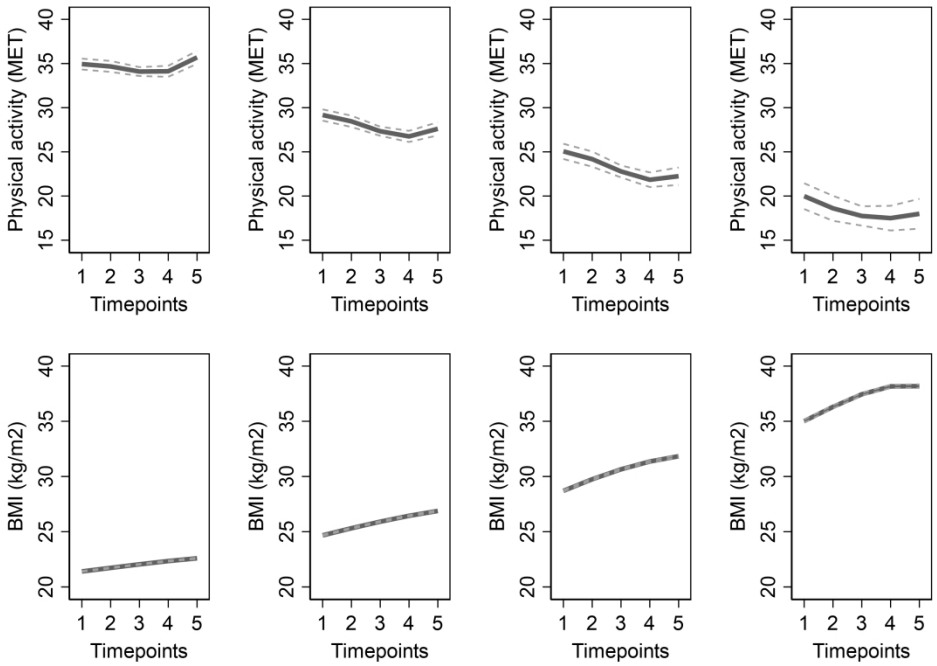

Figure 1. Trajectories of physical activity and body mass index amongst respondents <50 years95% confidence limits are shown as dot-lines. For BMI, very narrow 95% CIs are poorly separable in the figure. Time between responses is approximately four years.

700x510mm (120 x 120 DPI)

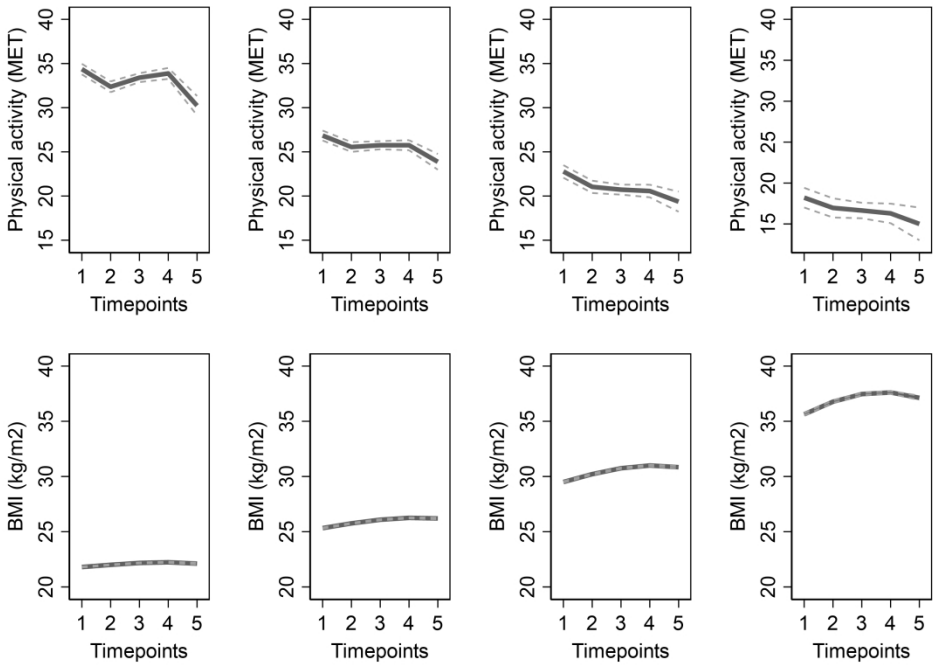

Figure 2. Trajectories of physical activity and body mass index amongst respondents > 50 years95% confidence limits are shown as dot-lines. For BMI, very narrow 95% CIs are poorly separable in the figure. Time between responses is approximately four years.

700x510mm (120 x 120 DPI)

Table E1. Goodness of fit of group-based trajectory analysis models. The chosen models are shown in bold.

Model	Smallest group		BIC[1]	AIC[2]	APP[3]
	n	%			
Men <51 years					
1-cluster	5,894	100%	-156,412	-156,369	1
2-cluster	1,469	25%	-151,020	-150,938	0.93
3-cluster	509	9%	-148,201	-148,080	0.91
4-cluster	**292**	**5%**	**-146,715**	**-146,555**	**0.88**
5-cluster	147	2%	-145,799	-145,600	0.86
Men >50 years					
1-cluster	7,490	100%	-177,574	-177,530	1
2-cluster	1,894	25%	-171,451	-171,368	0.92
3-cluster	622	8%	-168,332	-168,209	0.90
4-cluster	**334**	**4%**	**-166,442**	**-166,280**	**0.88**
5-cluster	174	2%	-165,267	-165,066	0.87
Women <51 years					
1-cluster	25,903	100%	-746,837	-746,786	1
2-cluster	6,530	25%	-715,572	-715,475	0.95
3-cluster	2,773	11%	-700,393	-700,250	0.92
4-cluster	**1,173**	**5%**	**-692,029**	**-691,840**	**0.90**
5-cluster	745	3%	-686,684	-686,449	0.87
Women >50 years					
1-cluster	27,565	100%	-690,012	-689,961	1
2-cluster	7,608	28%	-662,602	-662,506	0.94
3-cluster	3,164	11%	-649,085	-648,944	0.91
4-cluster	**1,536**	**6%**	**-641,136**	**-640,949**	**0.89**
5-cluster	842	3%	-636,666	-636,433	0.86

[1] BIC = Bayesian Information Criterion, [2] AIC = Akaike information criterion, [3] APP = Smallest average posterior probability

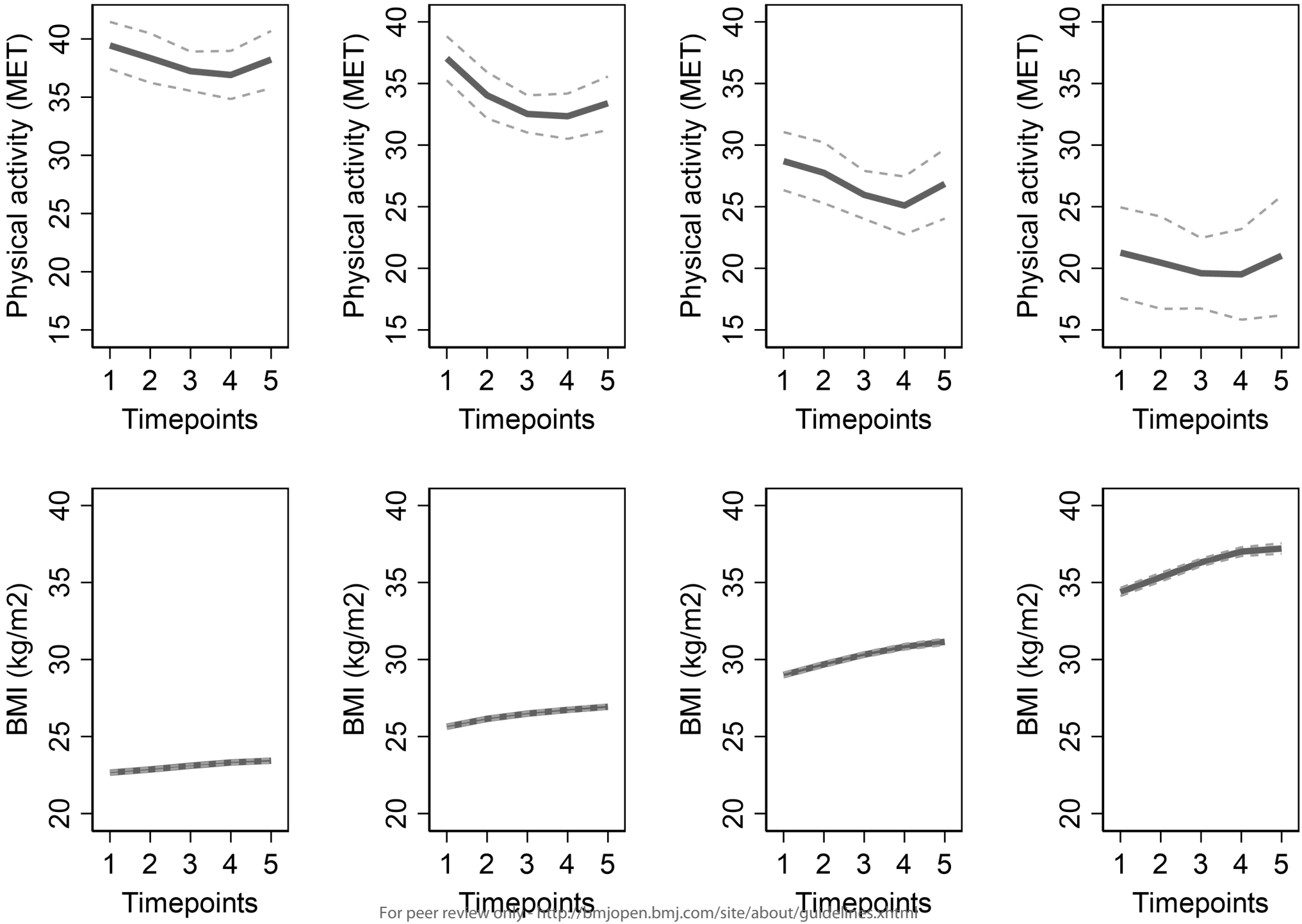

Figure E1. Trajectories of physical activity and body mass index (BMI) amongst men < 50 years
95% confidence limits are shown as dot-lines. For BMI, very narrow 95% CIs are poorly separable in the figure. Time between responses is approximately four years.

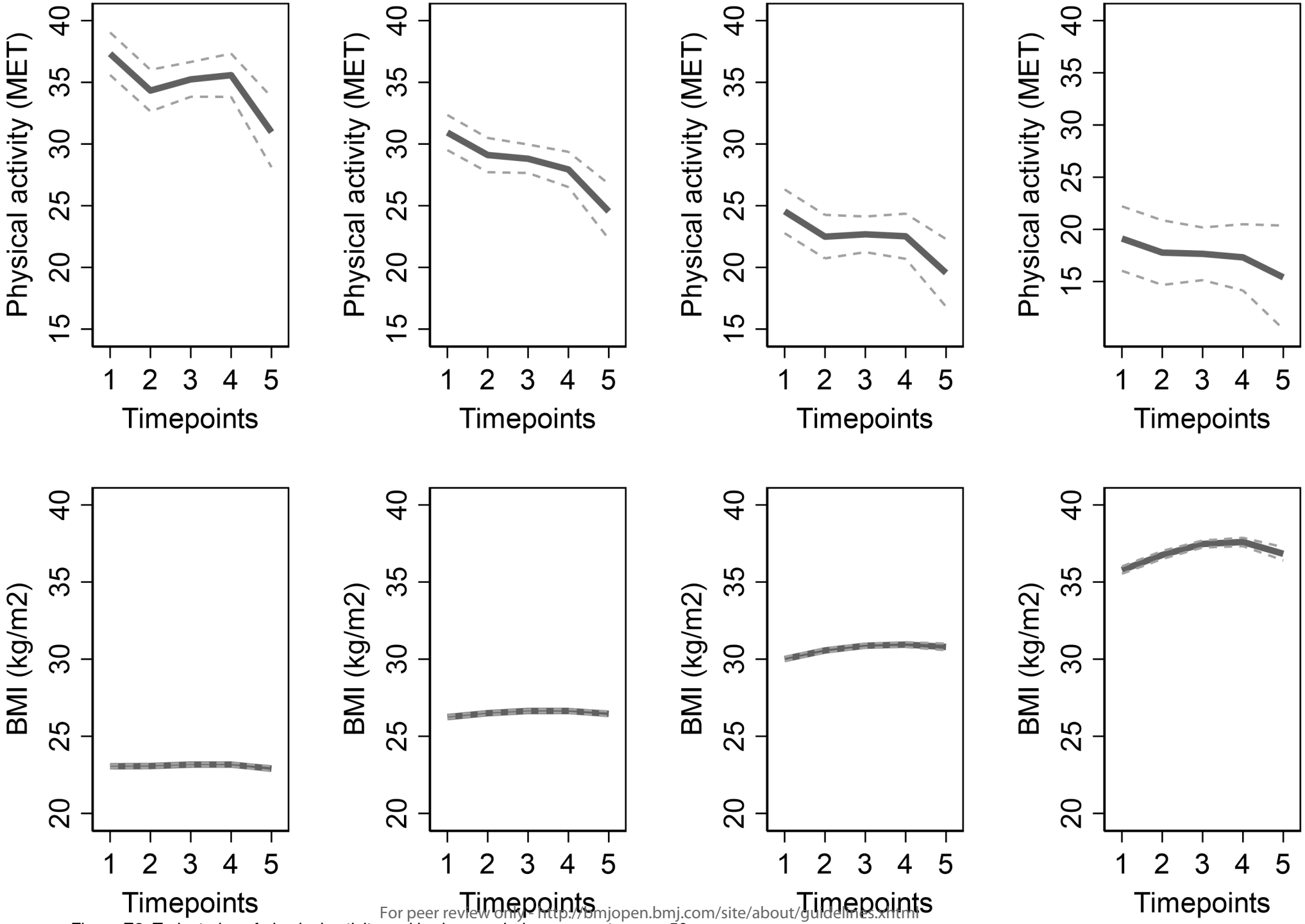

Figure E2. Trajectories of physical activity and body mass index amongst men > 50 years

95% confidence limits are shown as dot-lines. For BMI, very narrow 95% CIs are poorly separable in the figure. Time between responses is approximately four years.

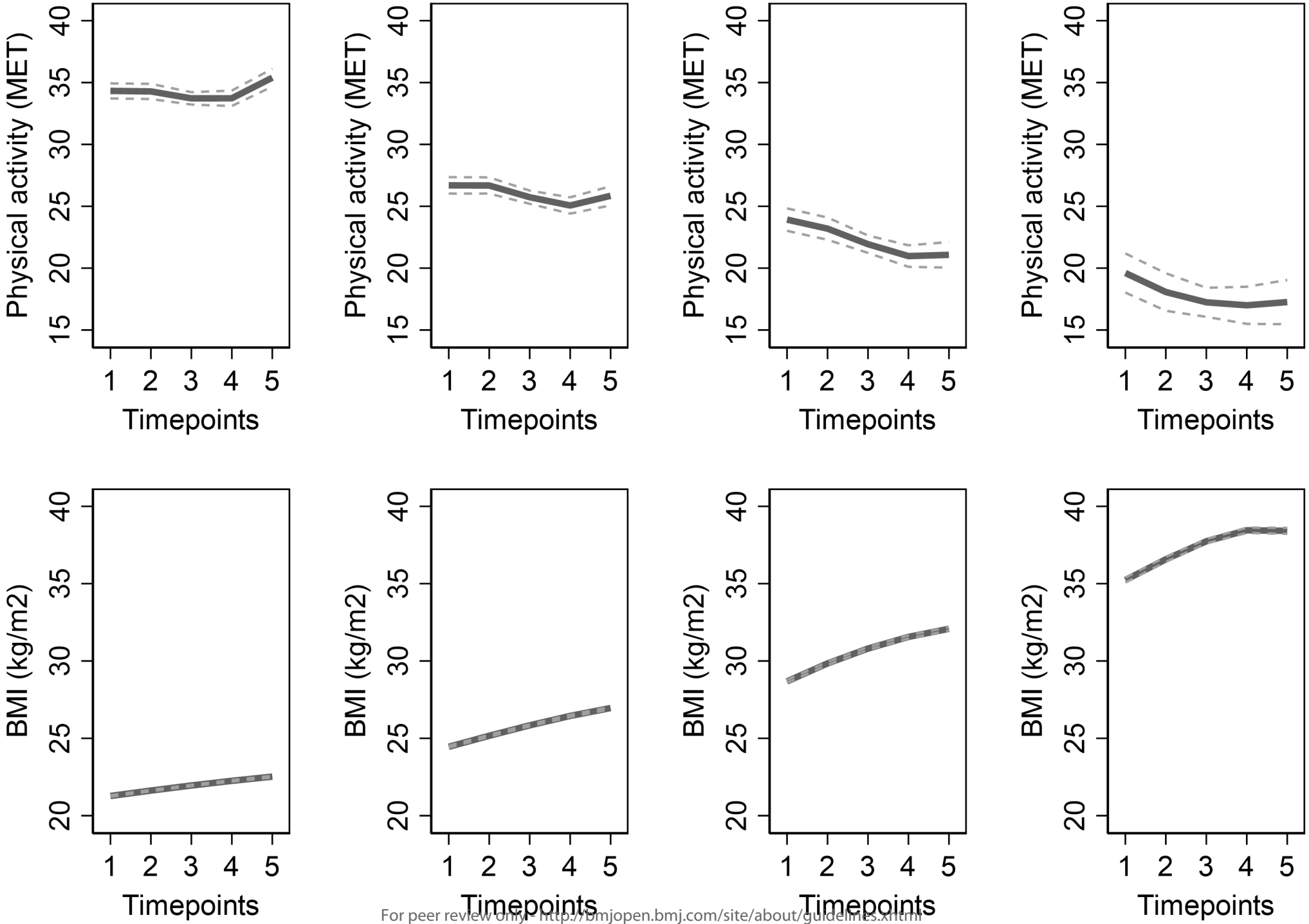

Figure E3. Trajectories of physical activity and body mass index amongst women < 50 years
95% confidence limits are shown as dot-lines. For BMI, very narrow 95% CIs are poorly separable in the figure. Time between responses is approximately four years.

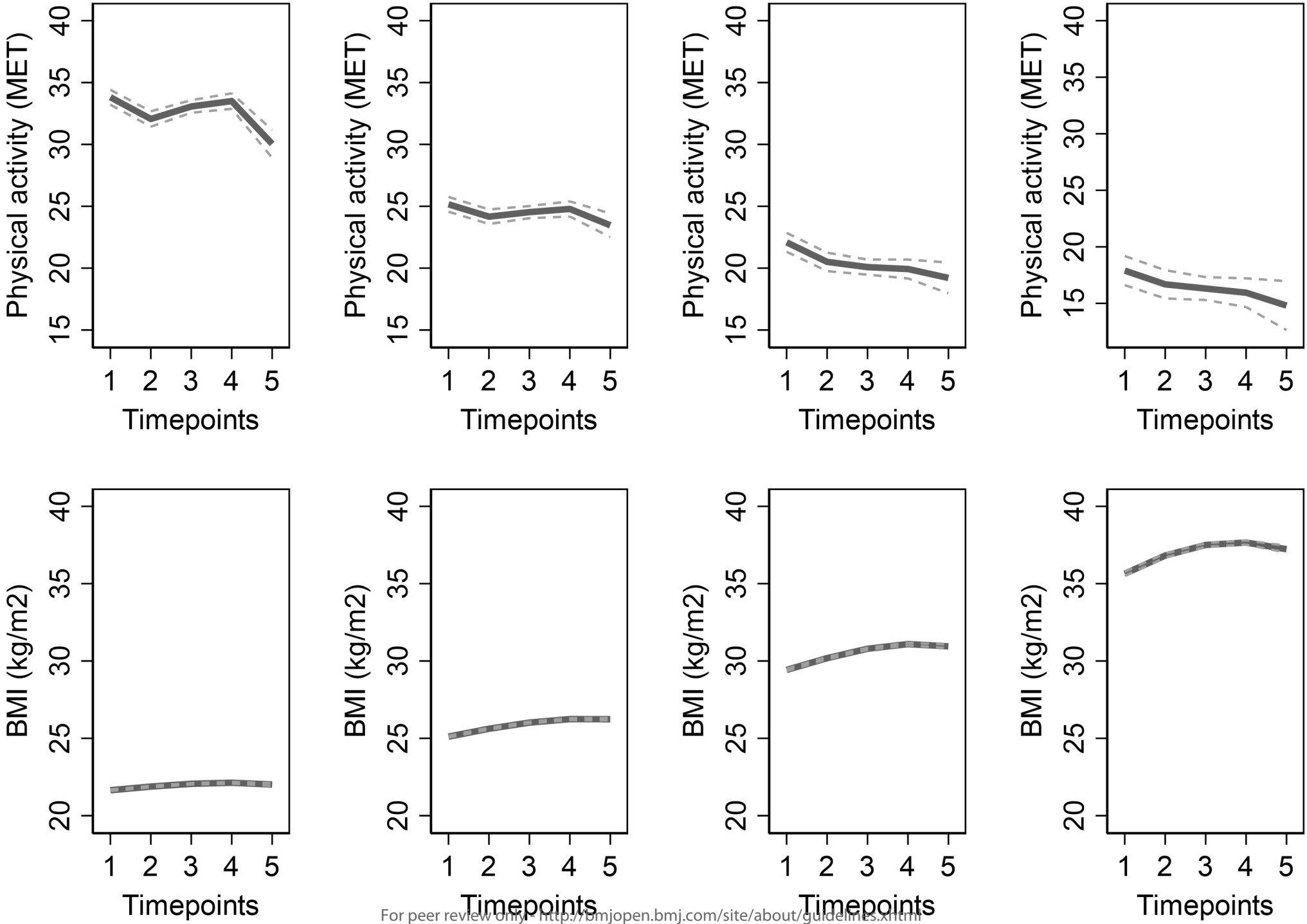

Figure E4. Trajectories of physical activity and body mass index amongst women > 50 years

95% confidence limits are shown as dot-lines. For BMI, very narrow 95% CIs are poorly separable in the figure. Time between responses is approximately four years.

STROBE Statement—Checklist of items that should be included in reports of ***cohort studies***

	Item No	Recommendation	Page No
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	4
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	6,7
Objectives	3	State specific objectives, including any prespecified hypotheses	7
Methods			
Study design	4	Present key elements of study design early in the paper	8
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	8
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up	8
		(*b*) For matched studies, give matching criteria and number of exposed and unexposed	
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	8
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	8
Bias	9	Describe any efforts to address potential sources of bias	9
Study size	10	Explain how the study size was arrived at	8
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	9
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	9
		(*b*) Describe any methods used to examine subgroups and interactions	9
		(*c*) Explain how missing data were addressed	9
		(*d*) If applicable, explain how loss to follow-up was addressed	
		(*e*) Describe any sensitivity analyses	9
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	10
		(b) Give reasons for non-participation at each stage	
		(c) Consider use of a flow diagram	
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	10
		(b) Indicate number of participants with missing data for each variable of interest	
		(c) Summarise follow-up time (eg, average and total amount)	
Outcome data	15*	Report numbers of outcome events or summary measures over time	10,11

Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included (*b*) Report category boundaries when continuous variables were categorized (*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	10,11
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	10,11
Discussion			
Key results	18	Summarise key results with reference to study objectives	12
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	13
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	12,13
Generalisability	21	Discuss the generalisability (external validity) of the study results	13
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	2

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at http://www.strobe-statement.org.

BMJ Open

Concurrent changes in physical activity and body mass index among 66,852 public sector employees over 16-year follow-up: multi-trajectory analysis of a cohort study in Finland

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Secondary Subject Heading:	Epidemiology
Keywords:	PUBLIC HEALTH, EPIDEMIOLOGY, QUALITATIVE RESEARCH

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Concurrent changes in physical activity and body mass index among 66,852 public sector employees over 16-year follow-up: multi-trajectory analysis of a cohort study in Finland

Running head: **Trajectories of physical activity and BMI**

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DECLARATIONS

Ethics approval and consent to participate:

The ethics committee of the Hospital District of Helsinki and Uusimaa approved the study (registration number HUS/1210/2016). Written informed consent to participate was obtained from each participant.

Consent for publication:

Not applicable

Data availability statement:

We are allowed to share anonymised questionnaire data of the Finnish Public Sector Study by application for with bona fide researchers with an established scientific record and bona fide organisations. For information about the Finnish Public Sector Study contact Prof. Mika Kivimaki mika.kivimaki[at]helsinki.fi / Dr. Jenni Ervasti jenni.ervasti[at]ttl.fi.

Competing interests:

The authors declare that they have no competing interests.

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Author contributions

All the authors (RT, MS, JE, MK, JP, SS, JV) substantially contributed to the conception and design of the work, the interpretation of the results and revising it critically for important intellectual content. JE, JV and MK were responsible for the acquisition of data for the work. MS and JP were responsible

for the statistical analysis. RT and MS were responsible for drafting the work. All the authors (RT, MS, JE, MK, JP, SS, JV) have finally approved the version to be published and they are agreed to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

Acknowledgements:

None to declare

Word count: 2496

References: 26

ABSTRACT

Objectives: To identify concurrent developmental trajectories of physical activity and body mass Index (BMI) over time.

Design: Prospective cohort study, repeated survey.

Setting: University research department and national institute of occupational health.

Participants: 66,852 public sector employees, who have been followed for 16 years.

Primary and secondary outcome measures: Shapes of trajectories of changes in physical activity and BMI.

Results At baseline, mean age was 44.7 (SD 9.4) years, BMI 25.1 (SD 4.1) kg/m^2 and physical activity 27.7 (SD 24.8) MET-h/week. Four clusters of concurrent BMI and physical activity trajectories were identified. There was negative association between BMI and physical activity.

Conclusions: Changes in BMI and physical activity might be interconnected. Decline in physical activity and increase in BMI were steeper among obese respondents with low level of physical activity.

Trial registration: The ethics committee of the Hospital District of Helsinki and Uusimaa approved the study (registration number HUS/1210/2016).

Keywords

“Physical activity”; “Body Mass Index”; "Population Dynamics"[Mesh]; "Population Characteristics"[Mesh]; “Population Health"[Mesh]; ("Prevalence"[Mesh]); "Longitudinal Studies"[Mesh]

Article Summary

Strengths and limitations of this study

- Large cohort of 66,852 participants
- Repeated measures of physical activity and BMI during 16 years
- Only leisure-time physical activity was taken into account leaving out work-related activity
- Self-reported nature of estimates of BMI and physical activity might lead to information bias

INTRODUCTION

Both obesity and physical inactivity have negative impact on multiple aspects of health and they increase the risk of mortality [1-3]. Ageing is associated with gaining weight and decreasing physical activity [4-6], but less is known whether these changes occur simultaneously and how much heterogeneity there is in the developmental trajectories of body weight and physical activity.

Few studies have examined heterogeneity in weight development over time more closely. A study amongst 30-year-old US war veterans identified five different, but all increasing, trajectories of body mass index (BMI) over 6-year follow-up [6]. However, the steepness of trajectories varied: while the non-obese participants showed only a small increase in BMI, the increase was much steeper among the participants with obesity. Another study from the US conducted on 60-year-old overweight participants identified seven weight trajectories of which most showed either stable overweight, continuously increasing BMI or relapse after weight loss. Even in the two trajectory groups showing decrease in BMI the participants remained overweight.[7].

Physical activity has also been reported to change over time. Leisure time physical activity among women has previously been reported to increase until age of 50 years and start to decrease after that.[4] For men, the change in leisure time physical activity has been reported to vary between different types of activity - while moderate physical activity increased, low and high levels decreased.[5] Studies concerning trajectories of physical activity have found variation in development of activity. A 22-year follow-up study from Canada among initially 18 to 60 year-olds has identified trajectories of consistently inactive, increasing, consistently active and decreasing leisure time physical activity.[8] Another study conducted in the US among 120 initially overweight people aged 54 (±9) years has measured activity with pedometers and identified ”sedentary” and ”low active” groups (decreasing daily count of steps), ”somewhat active” group (persistent daily count of steps) and ”active” group (increased daily count of steps) in 18-month follow-up.[9]

The association between higher levels of physical activity and lower BMI has been established in adults [10 11], and there has been some evidence that this association might be most pronounced

when physical activity exceeds 150 min/week.[10] There is, however, limited knowledge on simultaneous changes in these two factors. In short-term follow-up (18 months) among overweight 54-year-old Canadians, a trajectory with increasing activity has been associated with a trajectory of greater weight loss.[9] There is yet little knowledge on these two factors over longer follow-up. It is also unknown whether developmental patterns of BMI and physical activity differ by age or by gender.

To address the gap in the literature, the objective of this study was to examine concurrent changes in BMI and physical activity over 16-year follow-up by using a group-based multi-trajectory analysis. While conventional statistics show a trajectory of average change of outcome over time, group-based trajectory modeling can distinguish and describe subpopulations (clusters), which may differ substantially from each other and from the average trajectory seen in the entire population. The aim was also to examine, whether the distinguished trajectories are different for less than 50-year-olds and over 50-year-olds and whether the results are different when the study population is stratified by gender.

METHODS

Study population

Participants were drawn from the Finnish Public Sector (FPS) cohort study of employees of 10 towns and six hospital districts. The FPS has been described in detail elsewhere.[12 13] Data included responses to five questionnaire surveys administered to the FPS sub-cohorts in four-year intervals from 2000 to 2017 (average response rate 70%). The baseline was the response given in 2000 or 2004. Participants who had reported their BMI and physical activity in at least two waves were included in the analysis. The ethics committee of the Hospital District of Helsinki and Uusimaa approved the study (registration number HUS/1210/2016).

Physical activity was assessed with a questionnaire at all four-year intervals. The respondents were asked to estimate their average weekly hours of leisure-time physical activity/exercise and commuting activity within the previous year. The time spent on activity at each intensity level in hours per week was multiplied by the average energy expenditure of each activity, expressed in metabolic equivalent of task (MET). [14] The MET is a ratio of rate of energy expenditure reflecting the amount of consumed energy compared to resting. One MET unit of 3.5 ml of oxygen per kg per minute corresponds to oxygen consumption when calmly sitting down. Weekly physical activity was expressed as MET-h/week and categorized as low (<14 MET-h/week), moderate (14 to <30 MET-h/week) or high (≥30 MET-h/week) physical activity levels.[15 16] The definition of physical activity in the survey is presented in table 1. As recommended by the American Heart Association, 150 minutes of moderate-intensity aerobic exercise each week is needed for optimal cardiovascular health. That is equal to about 8.3 MET-h/week.

The BMI was defined as weight/height^2 (kg/m^2) based on self-reported body weight and height. The interpretation of the mean level of BMI trajectories was based on the following categorization: normal weight (<25 kg/m^2), overweight (25 to 29.9 kg/m^2), obese (30-34.9 kg/m^2) and severely obese (≥35

kg/m^2). Of the respondents, only 934 (1%) had BMI ≤18.5, and thus, for the matter of clarity, BMI <25 was considered "normal". Age was defined in full years. The cohort was divided in two approximately even age groups: <=50 (n=31,797, 48%) and >50 years (n=35,055, 52%).

Statistical analysis

The characteristics of participants were reported as means and standard deviations or as absolute numbers and percentage when appropriate.

Group-based multi-trajectory analysis (GBTA) was used to distinguish different developmental trajectories for physical activity and BMI, both treated as continuous variables. A censored (known also as 'regular') normal model of group-based multi-trajectory analysis was used. The goodness of model fit was judged by running the procedure several times with a number of subpopulations starting from one up to six. The Bayesian Information Criterion (BIC), Akaike information criterion (AIC) and average posterior probability (APP) were used as criteria to confirm the goodness of fit. A cubic regression was applied. The cut-off for the smallest group was set at ≥5%. The trajectory analysis was conducted on two age-groups ≤50 and >50 years as previous studies have suggested that changes in BMI and physical activity may vary depending on the age [17 18]. The sensitivity analysis was conducted by dividing both age groups by gender. No adjustments for co-variables were made.

All the analyses were performed using Stata/IC Statistical Software: Release 16. College Station (StataCorp LP, TX, USA). The additional Stata module 'traj' was required to conduct group-based trajectory analysis. The module is freely available for both SAS® and Stata software (Jones and Nagin 1999; 2013).

Patient and public involvement

Participants of research were not involved in setting the study question and outcome measures and were not involved in the design and implementation of the study or writing the manuscript.

RESULTS

During the 16-year follow-up, the 66,852 participants had reported body weight and height on average in 3.5 (SD 1.3) study waves and physical activity in 3.6 (SD 1.3) study waves. The sample was predominated by 53,468 women (80%). In the younger group (≤ 50-year-olds) mean age was 39.8 (SD 7.2), BMI at baseline was 24.6 (SD 4.0) kg/m^2 and average physical activity was 28.8. (SD 25.5) MET-h/week. In the older group (>50-year-olds), age was 55.0 (SD 2.9), BMI 25.6 (SD 4.2) kg/m^2 and physical activity 26.7 (SD 24.1) MET-h/week.

A four-trajectory model was chosen as the five-trajectory model had resulted in a smallest group below a pre-agreed cut-off of 5% (Table 2). Four concurrent trajectories of BMI and physical activity were identified for both age groups (Figure 1 and Figure 2):

1. Group 1 (38% among ≤ 50 years, 32% among > 50 years): Individuals with normal weight (BMI <25 kg/m^2) and high level of physical activity (30-35 MET-h/week).
2. Group 2 (39% among ≤ 50 years, 42% among > 50 years): Individuals with overweight (BMI 25 to 30 kg/m^2) and moderately high level of physical activity (25-30 MET-h/week).
3. Group 3 (18% among ≤ 50 years, 21% among > 50 years): Individuals with obesity (BMI 30 to 35 kg/m^2) and moderately low level of physical activity (20-25 MET-h/week).
4. Group 4 (5% among ≤ 50 years, 5% among > 50 years): Individuals with severe obesity (BMI >35 kg/m^2) and low level of physical activity (<20 MET-h/week).

Group 1: Individuals with normal weight and high level of physical activity

In this group, the younger respondents demonstrated a stable high level of physical activity with a slight rise towards the end of follow-up and their BMI increased slightly throughout the follow-up. For the older respondents, the level of physical activity decreased markedly during the follow-up, even if there was a slight rising pattern in the middle of follow-up. At the same time, the trajectory of BMI remained flat.

Group 2: Individuals with overweight and moderately high level of physical activity

In this group, the level of physical activity declined in both age groups, but the decline was steeper among the older respondents. In younger respondents, the decrease of physical activity slowed down slightly towards the end of follow-up. Simultaneously, BMI was steadily growing among younger respondents, while remaining relatively flat in older group.

Group 3: Individuals with obesity and moderately low level of physical activity

The physical activity and BMI trajectories were similar to the trajectories observed in group of overweight individuals with moderately high level of physical activity (group #2), but with a slightly steeper decline in physical activity and steeper increase in BMI.

Group 4: Individuals with severe obesity and low level of physical activity

Also in this group, physical activity decreased and BMI increased. In younger respondents, this development slowed down at the end follow-up for both physical activity and BMI. Instead, in older respondents, the decrease in physical activity accelerated towards the end of follow-up with simultaneous slight decline in BMI.

Sensitivity analysis

Stratifying the respondents by gender in addition to age resulted in similar findings with few exceptions (supplementary figures E1-E4 and supplementary table E1). Among normal weight or overweight respondents, the decline in physical activity was steeper among men compared to women.

DISCUSSION

This prospective cohort study in 66,852 public sector employees followed repeatedly by 4-year intervals investigated trajectories of concurrent changes in BMI and physical activity over 16 years. Four trajectory clusters were identified for both participants aged ≤50 and for those >50 years: 1) individuals with normal weight and high level of physical activity; 2) individuals with overweight and moderately high level of physical activity; 3) individuals with obesity and moderately low level of physical activity; and 4) individuals with severe obesity and low level of physical activity. On average, BMI increased and physical activity decreased during the follow-up. Some trajectories demonstrated, however, distinctive features. Over time, the respondents with normal weight or overweight gained only a little weight while preserved a high or moderately high level of physical activity, even if the intensity of physical activity mildly decreased especially in older respondents. The decrease in physical activity and increase in BMI were steeper among the respondents with obesity or severe obesity, who had moderately low or low level of physical activity already at the start of the follow-up. Among the normal weight or overweight respondents, decline in physical activity was steeper among men compared to women.

The observed age-related weight gain is in line with previous studies [4-6 19], as well as the decline in physical activity [4 20 21]. Previous studies have also shown that an increase in BMI slows down with advancing age, and this was also supported by the present findings – the rise in BMI was steeper in the younger respondents [22 23]. During the follow-up, the decline in physical activity mirrored the increase in BMI. Similar findings have been reported before – several studies conducted among middle-aged adults have observed an association between physical activity and weight gain [10 11 24 25]. This association has been described to be dose-dependent – physically active individuals gain less weight than inactive peers. [11] Current results support this finding, since the increase in BMI was less steep in the more active groups. The amount of activity needed to prevent weight gain has been debated. Some studies have concluded that current activity recommendations are not sufficient enough to prevent weight gain and that there is a need for higher activity to remain in the normally

weighted category [10 11 24]. This is in line with the current findings – only high physical activity was associated with normal weight.

The strengths of the study were long follow-up of 16 years, repeated measurements on physical activity and BMI, and a large sample size. For our knowledge, there are no previous multi-trajectory analyses of the relation between physical activity and BMI conducted in adults.

The study has also some limitations. Physical activity was self-reported and only leisure-time and commuting activity were inquired. Thus, physical activity at work was not considered. The distribution of physical activity intensity was skewed – most of the participants were at least somewhat active, and even in the least active group the mean activity level was approximately 18 MET-h/week, which is approximately the equivalent of three hours of brisk walking weekly. BMI was also based on self-reported weight and height, which may cause recall and information bias, possibly resulting in under-reporting of body weight [26]. Most of the participants had BMI above 25 indicating overweight or obesity (62% in the age group of ≤50 years and 68% in the older), which may reflect the current overweight and obesity pandemic. The cohort included predominantly working-age women employed in public sector. Therefore, the results might not be directly reflected on the entire population, since there might be variation in behavior, for instance among unemployed people or entrepreneurs. Moreover, a public sector often employs people with higher socioeconomic status, who might have more knowledge and financial resources to healthy lifestyle choices compared to manual workers.

The results may be of interest for both clinicians and stockholders when applying measures targeting increasing physical activity and controlling weight especially among people of middle-age. Additionally, the information on the established trajectories may give people more motivation to change their health behavior. Further research may reveal risk factors that affect developmental trajectories seen in this study. Such factors may be, for example, gender, socio-economic status, smoking, alcohol consumption and concurrent health disorders among others.

Conclusions

Changes in BMI and physical activity might be interconnected. The normal weight or overweight respondents gained only a little weight while preserved a high or moderately high level of physical activity. Compared to normal weight trajectories, the decrease of physical activity and increase in BMI were markedly steeper among the obese or severely obese trajectories, who also had moderately low or low level of physical activity. The findings were similar for both age groups. Among the normal weight and overweight trajectories, decline in physical activity was steeper among men compared to women. Since physical inactivity and overweight are both risk factors for many diseases, more research is needed to develop interventions that could simultaneously affect both.

LIST OF ABBREVIATIONS

BMI: Body Mass Index

FPS: Finnish Public Sector cohort study

MET: Metabolic Equivalent of Task

FIGURE LEGENDS

Figure 1. Trajectories of physical activity and body mass index amongst respondents ≤50 years

95% confidence limits are shown as dot-lines. For BMI, very narrow 95% CIs are poorly separable in the figure. Time between responses is approximately four years.

Figure 2. Trajectories of physical activity and body mass index amongst respondents > 50 years

95% confidence limits are shown as dot-lines. For BMI, very narrow 95% CIs are poorly separable in the figure. Time between responses is approximately four years.

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366 **TABLES**

367 Table 1. Defining the level of physical activity in the survey.

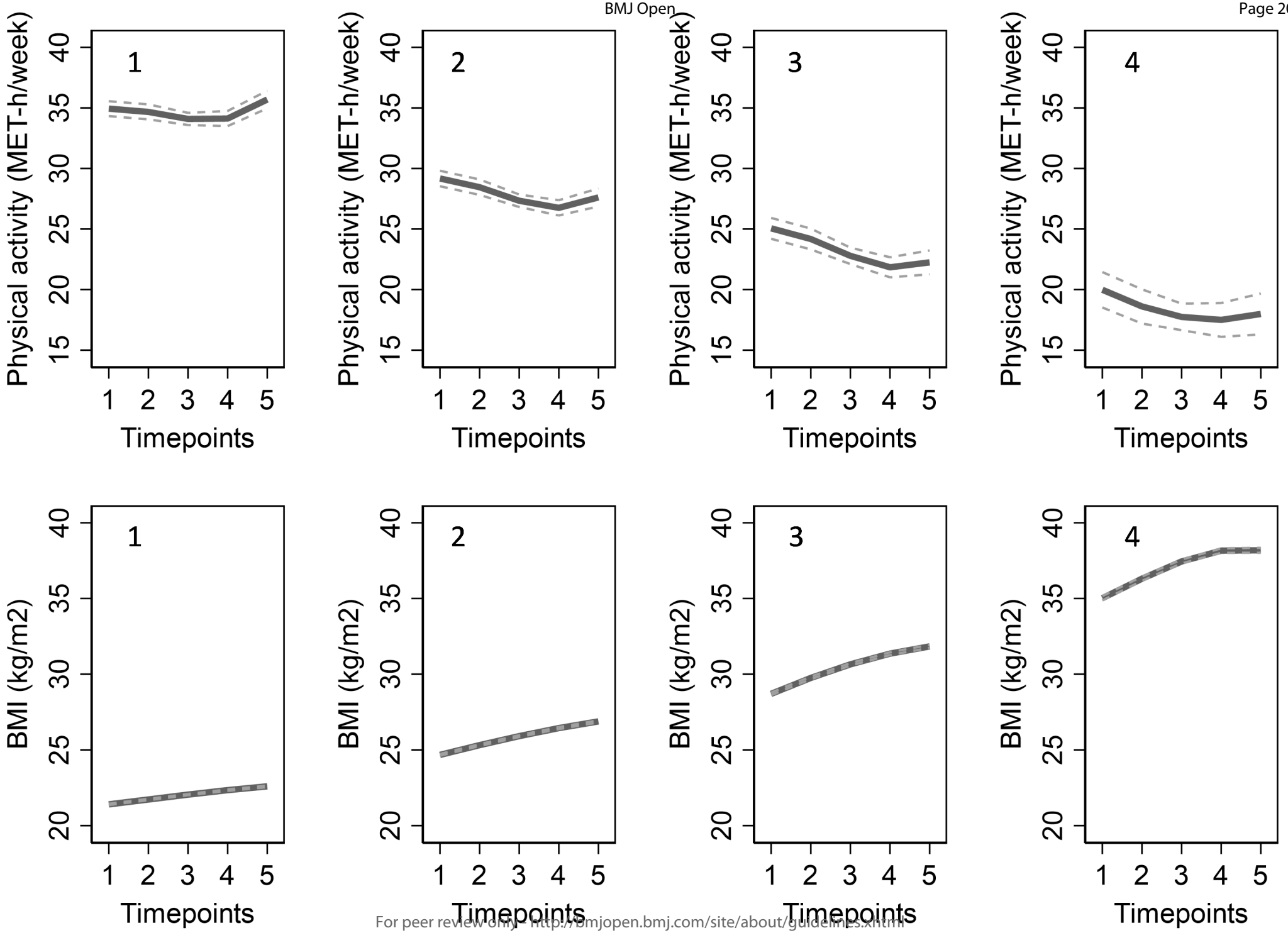
What was the intensity and frequency of your average physical activity (leisure or commuting) during the past year (or since the onset of your disease if the disease had begun less than a year ago)?					
Intensity (Mark all four options)	Amount per week				
	None	<½ hour	1 hour	2 – 3 hours	≥ 4 hours
Normal walking or respective					
Brisk walking or respective					
Light jogging or respective					
Brisk jogging or respective					
The responses were converted into MET units according to a following scheme.					
Intensity (Mark all four options)	MET minutes per week				
	None	<½ hour	1 hour	2 – 3 hours	≥ 4 hours
Normal walking or respective	0	69	138	345	550
Brisk walking or respective	0	99	198	495	792
Light jogging or respective	0	210	420	1050	1680
Brisk jogging or respective	0	240	480	1200	1920

368

Table 2. Goodness of fit of group-based trajectory analysis models. The chosen models are shown in bold.

Model	Smallest group		BIC[1]	AIC[2]	APP[3]
	n	%			
≤50 years					
1-cluster model	31,797	100%	-905,561	-905,509	1
2-cluster model	8,234	26%	-869,531	-869,432	0.94
3-cluster model	3,331	10%	-851,542	-851,397	0.92
4-cluster model	**1,490**	**5%**	**-841,703**	**-841,510**	**0.89**
5-cluster model	898	3%	-835,396	-835,157	0.87
>50 years					
1-cluster model	35,055	100%	-869,200	-869,148	1
2-cluster model	9,690	28%	-836,174	-836,076	0.93
3-cluster model	3,845	11%	-819,600	-819,454	0.91
4-cluster model	**1,888**	**5%**	**-809,601**	**-809,409**	**0.89**
5-cluster model	999	3%	-803,977	-803,738	0.87

[1] BIC = Bayesian Information Criterion, [2] AIC = Akaike information criterion, [3] APP = Smallest average posterior probability


1
2
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4
Physical activity (MET-h/week)
BMI (kg/m2)
Timepoints
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20
25
30
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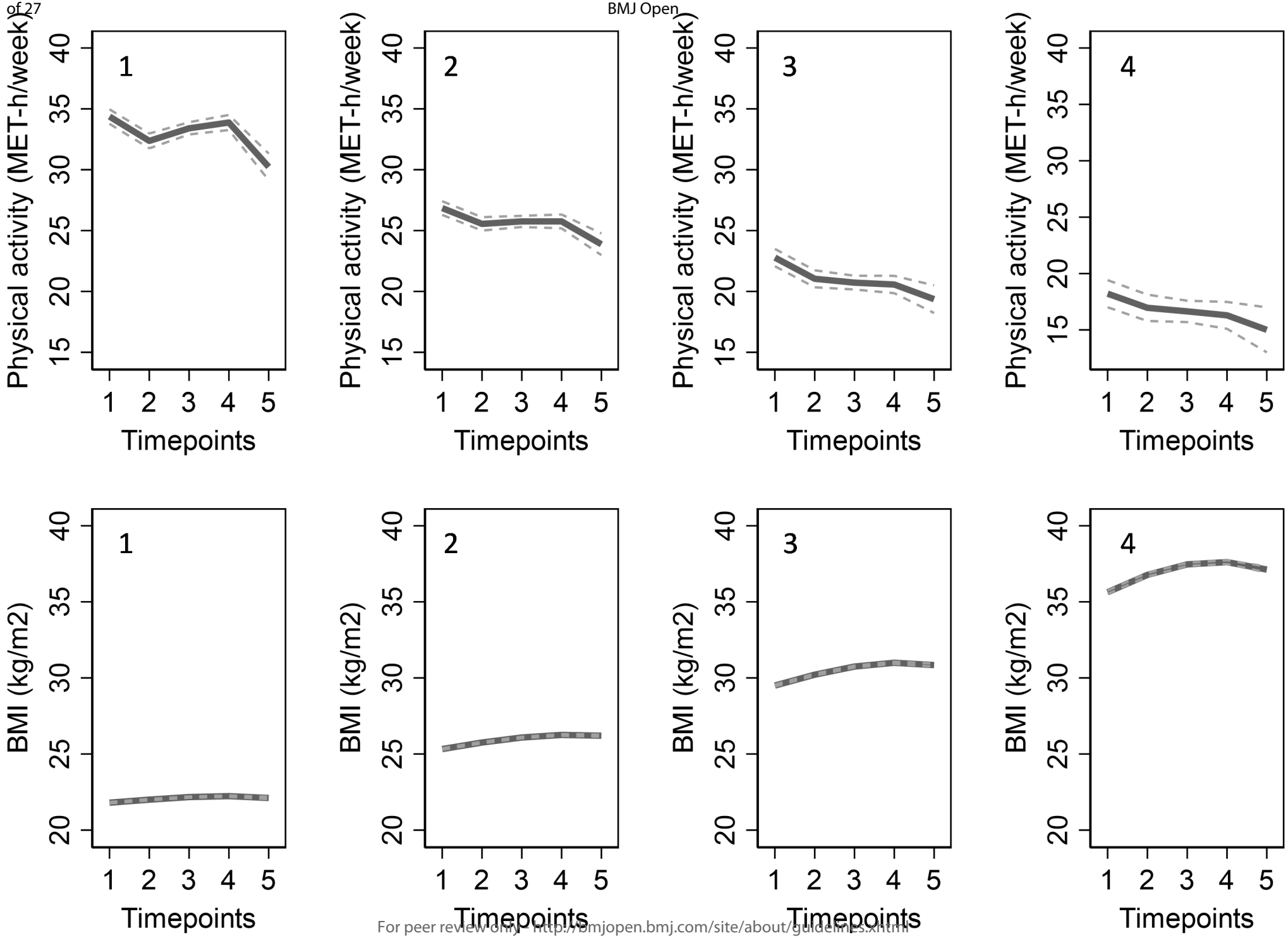
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Physical activity (MET-h/week)
BMI (kg/m2)
Timepoints
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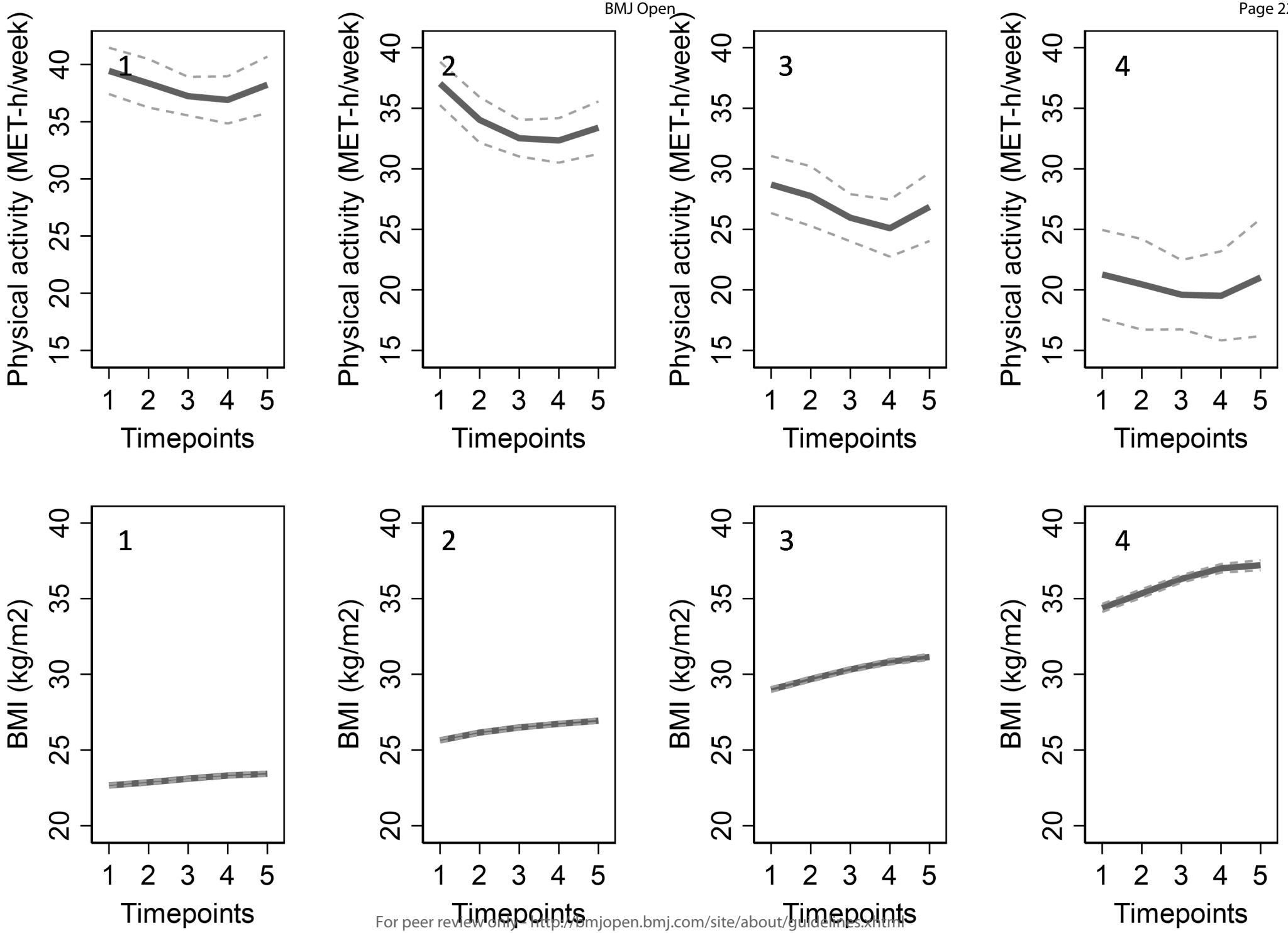

Figure E1. Trajectories of physical activity and body mass index (BMI) amongst men < 50 years
95% confidence limits are shown as dot-lines. For BMI, very narrow 95% CIs are poorly separable in the figure. Time between responses is approximately four years.

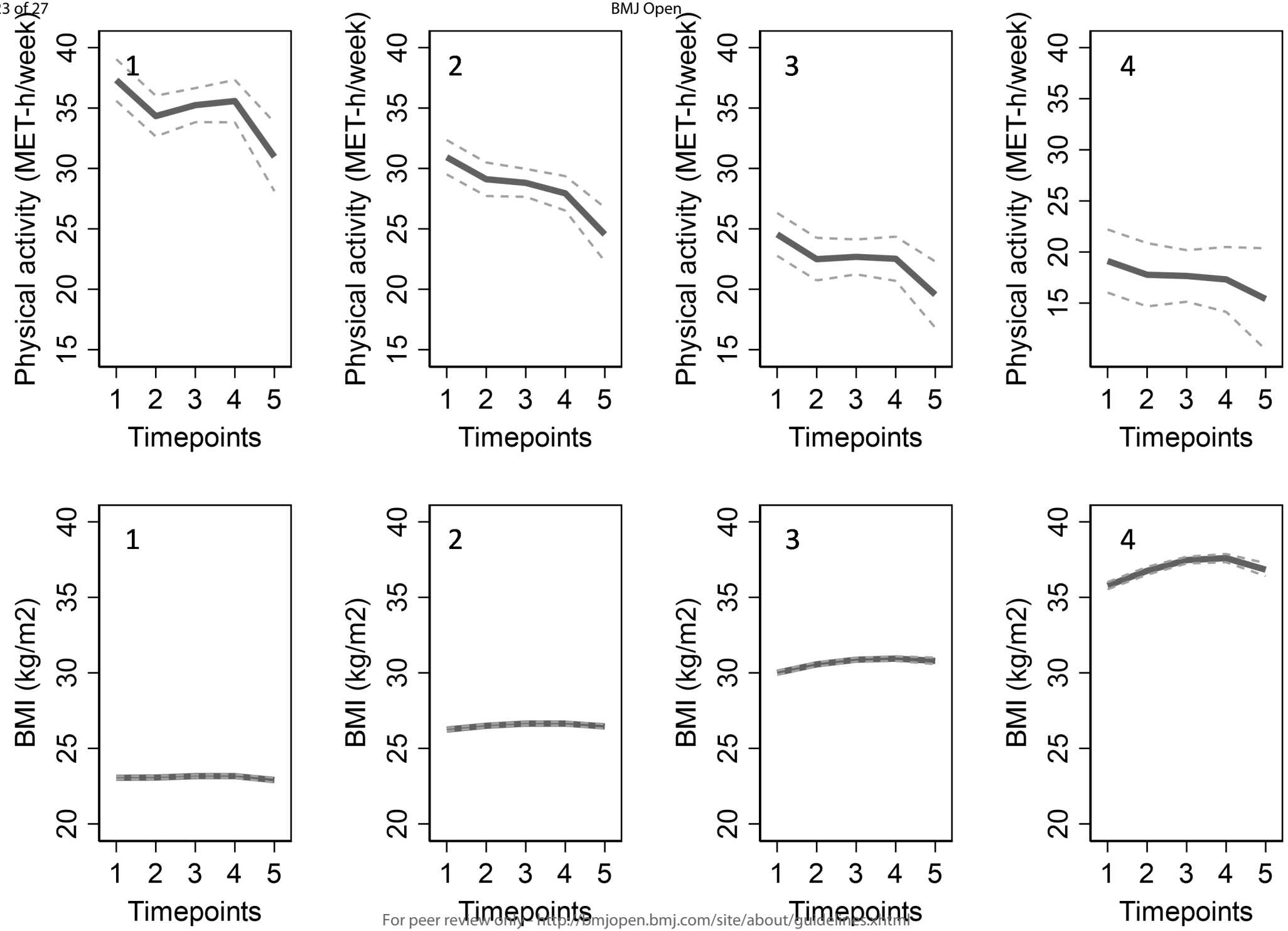

Figure E2. Trajectories of physical activity and body mass index amongst men > 50 years
95% confidence limits are shown as dot-lines. For BMI, very narrow 95% CIs are poorly separable in the figure. Time between responses is approximately four years.

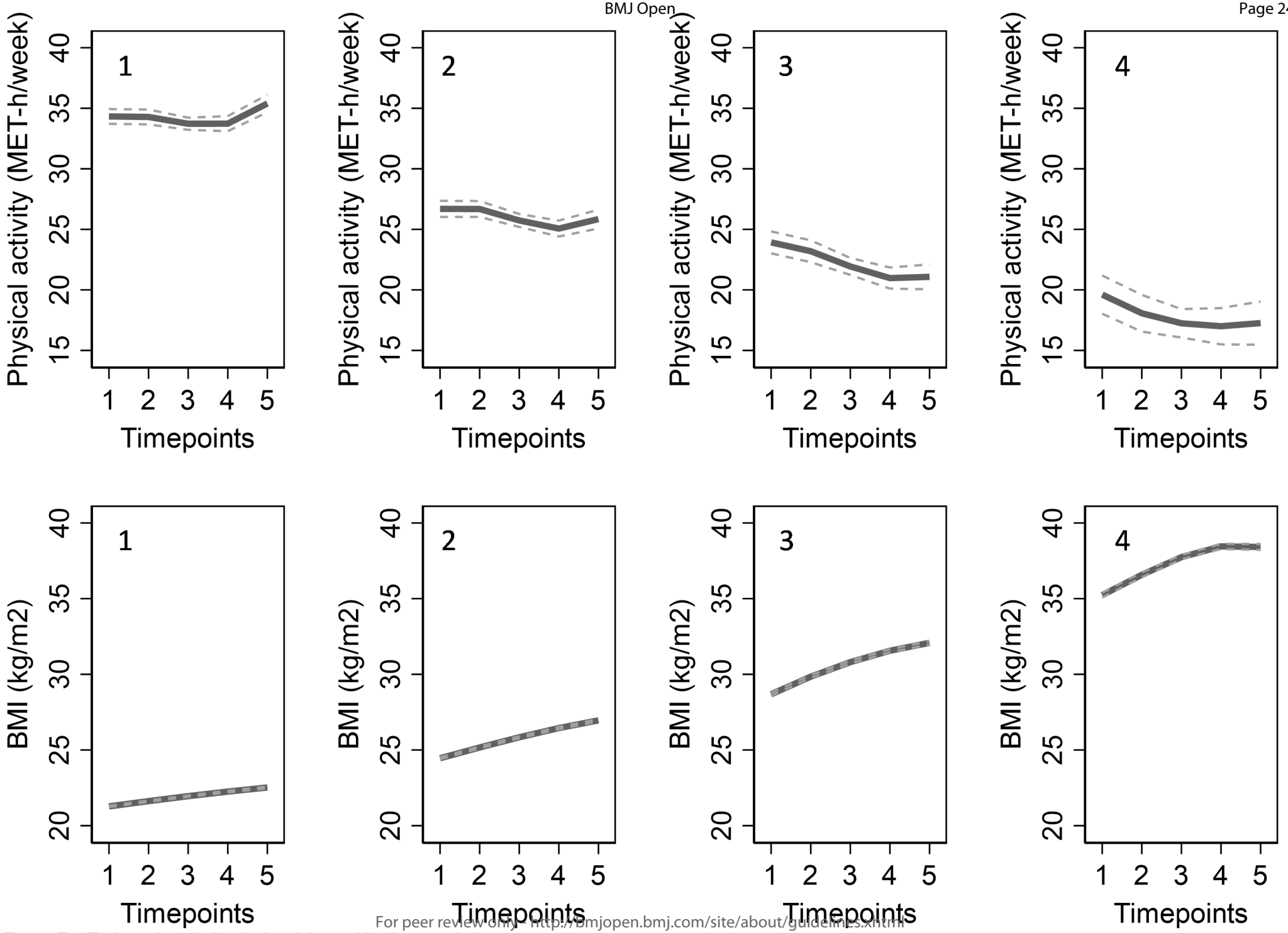

Figure E3. Trajectories of physical activity and body mass index amongst women < 50 years
95% confidence limits are shown as dot-lines. For BMI, very narrow 95% CIs are poorly separable in the figure. Time between responses is approximately four years.

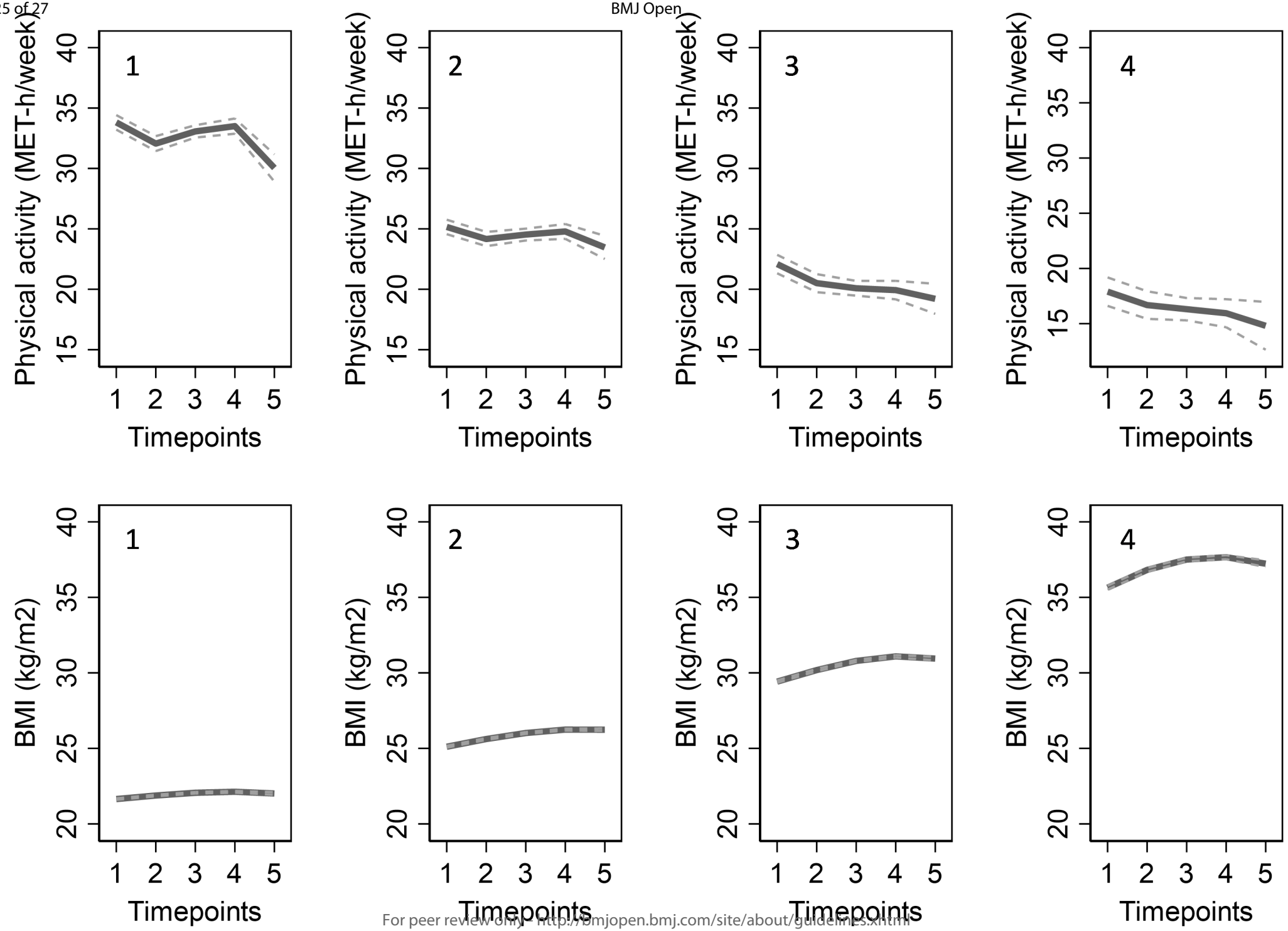

Figure E4. Trajectories of physical activity and body mass index amongst women > 50 years
95% confidence limits are shown as dot-lines. For BMI, very narrow 95% CIs are poorly separable in the figure. Time between responses is approximately four years.

Table E1. Goodness of fit of group-based trajectory analysis models. The chosen models are shown in bold.

Model	Smallest group		BIC[1]	AIC[2]	APP[3]
	n	%			
Men <51 years					
1-cluster	5,894	100%	-156,412	-156,369	1
2-cluster	1,469	25%	-151,020	-150,938	0.93
3-cluster	509	9%	-148,201	-148,080	0.91
4-cluster	**292**	**5%**	**-146,715**	**-146,555**	**0.88**
5-cluster	147	2%	-145,799	-145,600	0.86
Men >50 years					
1-cluster	7,490	100%	-177,574	-177,530	1
2-cluster	1,894	25%	-171,451	-171,368	0.92
3-cluster	622	8%	-168,332	-168,209	0.90
4-cluster	**334**	**4%**	**-166,442**	**-166,280**	**0.88**
5-cluster	174	2%	-165,267	-165,066	0.87
Women <51 years					
1-cluster	25,903	100%	-746,837	-746,786	1
2-cluster	6,530	25%	-715,572	-715,475	0.95
3-cluster	2,773	11%	-700,393	-700,250	0.92
4-cluster	**1,173**	**5%**	**-692,029**	**-691,840**	**0.90**
5-cluster	745	3%	-686,684	-686,449	0.87
Women >50 years					
1-cluster	27,565	100%	-690,012	-689,961	1
2-cluster	7,608	28%	-662,602	-662,506	0.94
3-cluster	3,164	11%	-649,085	-648,944	0.91
4-cluster	**1,536**	**6%**	**-641,136**	**-640,949**	**0.89**
5-cluster	842	3%	-636,666	-636,433	0.86

[1] BIC = Bayesian Information Criterion, [2] AIC = Akaike information criterion, [3] APP = Smallest average posterior probability

STROBE Statement—Checklist of items that should be included in reports of ***cohort studies***

	Item No	Recommendation	Page No
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	4
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	6,7
Objectives	3	State specific objectives, including any prespecified hypotheses	7
Methods			
Study design	4	Present key elements of study design early in the paper	8
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	8
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up	8
		(*b*) For matched studies, give matching criteria and number of exposed and unexposed	
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	8
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	8
Bias	9	Describe any efforts to address potential sources of bias	9
Study size	10	Explain how the study size was arrived at	8
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	9
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	9
		(*b*) Describe any methods used to examine subgroups and interactions	9
		(*c*) Explain how missing data were addressed	9
		(*d*) If applicable, explain how loss to follow-up was addressed	
		(*e*) Describe any sensitivity analyses	9
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	10
		(b) Give reasons for non-participation at each stage	
		(c) Consider use of a flow diagram	
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	10
		(b) Indicate number of participants with missing data for each variable of interest	
		(c) Summarise follow-up time (eg, average and total amount)	
Outcome data	15*	Report numbers of outcome events or summary measures over time	10,11

Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included (*b*) Report category boundaries when continuous variables were categorized (*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	10,11
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	10,11
Discussion			
Key results	18	Summarise key results with reference to study objectives	12
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	13
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	12,13
Generalisability	21	Discuss the generalisability (external validity) of the study results	13
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	2

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at http://www.strobe-statement.org.

BMJ Open

Concurrent changes in physical activity and body mass index among 66,852 public sector employees over a 16-year follow-up: multi-trajectory analysis of a cohort study in Finland

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Secondary Subject Heading:	Epidemiology
Keywords:	PUBLIC HEALTH, EPIDEMIOLOGY, QUALITATIVE RESEARCH

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Concurrent changes in physical activity and body mass index among 66,852 public sector employees over a 16-year follow-up: multi-trajectory analysis of a cohort study in Finland

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DECLARATIONS

Ethics approval and consent to participate:

The ethics committee of the Hospital District of Helsinki and Uusimaa approved the study (registration number HUS/1210/2016). Written informed consent to participate was obtained from each participant.

Consent for publication:

Not applicable

Data availability statement:

We are allowed to share anonymised questionnaire data of the Finnish Public Sector Study by application for with bona fide researchers with an established scientific record and bona fide organisations. For information about the Finnish Public Sector Study contact Prof. Mika Kivimaki mika.kivimaki[at]helsinki.fi / Dr. Jenni Ervasti jenni.ervasti[at]ttl.fi.

Competing interests:

The authors declare that they have no competing interests.

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Author contributions

All the authors (RT, MS, JE, MK, JP, SS, JV) substantially contributed to the conception and design of the work, the interpretation of the results and revising it critically for important intellectual content. JE, JV and MK were responsible for the acquisition of data for the work. MS and JP were responsible

for the statistical analysis. RT and MS were responsible for drafting the work. All the authors (RT, MS, JE, MK, JP, SS, JV) have finally approved the version to be published and they are agreed to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

Word count: 2632

References: 28

ABSTRACT

Objectives: To identify concurrent developmental trajectories of physical activity and body mass index (BMI) over time.

Design: Prospective cohort study, repeated survey.

Setting: Cohort study in Finland.

Participants: 66,852 public sector employees, who have been followed up for 16 years.

Outcome measures: Shapes of trajectories of changes in physical activity and BMI.

Results: At baseline, mean age was 44.7 (SD 9.4) years, BMI 25.1 (SD 4.1) kg/m^2 and physical activity 27.7 (SD 24.8) MET-h/week. Four clusters of concurrent BMI and physical activity trajectories were identified: 1) normal weight (BMI <25 kg/m^2) and high level of physical activity (30-35 MET-h/week), 2) overweight (BMI 25 to 30 kg/m^2) and moderately high level of physical activity (25-30 MET-h/week), 3) obesity (BMI 30 to 35 kg/m^2) and moderately low level of physical activity (20-25 MET-h/week) and 4) severe obesity (BMI >35 kg/m^2) and low level of physical activity (<20 MET-h/week). In general, BMI increased and physical activity decreased during the follow-up. Decline in physical activity and increase in BMI were steeper among obese respondents with low level of physical activity.

Conclusions: Changes in BMI and physical activity might be interconnected. The results may be of interest for both clinicians and other stakeholders with respect to informing measures targeting increasing physical activity and controlling weight, especially among middle-aged people. Additionally, the information on the established trajectories may give individuals motivation to change their health behavior.

Keywords

“Physical activity”; “Body Mass Index”; "Population Dynamics"[Mesh]; "Population Characteristics"[Mesh]; “Population Health"[Mesh]; ("Prevalence"[Mesh]); "Longitudinal Studies"[Mesh]

Article Summary

Strengths and limitations of this study

- Large cohort of 66,852 participants.
- Repeated measures of physical activity and BMI over 16 years.
- Only leisure-time physical activity was taken into account, leaving out work-related activity.
- The self-reported nature of estimates of BMI and physical activity might lead to information bias.

INTRODUCTION

Both obesity and physical inactivity have negative impact on multiple aspects of health and they increase the risk of mortality [1-3]. Ageing is associated with gaining weight and decreasing physical activity [4-6], but less is known whether these changes occur simultaneously and how much heterogeneity there is in the developmental trajectories of body weight and physical activity.

Few studies have examined heterogeneity in weight development over time more closely. A study amongst 30-year-old US war veterans identified five different, but all increasing, trajectories of body mass index (BMI) over 6-year follow-up [6]. However, the steepness of trajectories varied: while the non-obese participants showed only a small increase in BMI, the increase was much steeper among the participants with obesity. Another study from the US conducted on 60-year-old overweight participants identified seven weight trajectories of which most showed either stable overweight, continuously increasing BMI or relapse after weight loss. Even in the two trajectory groups showing decrease in BMI the participants remained overweight.[7].

Physical activity has also been reported to change over time. Leisure time physical activity among women has previously been reported to increase until age of 50 years and start to decrease after that.[4] For men, the change in leisure time physical activity has been reported to vary between different types of activity - while moderate physical activity increased, low and high levels decreased.[5]

Studies concerning trajectories of physical activity have found variation in development of activity. A 22-year follow-up study from Canada among initially 18 to 60 year-olds has identified trajectories of consistently inactive, increasing, consistently active and decreasing leisure time physical activity.[8] Another study conducted in the US among 120 initially overweight people aged 54 (±9) years has measured activity with pedometers and identified ”sedentary” and ”low active” groups (decreasing daily count of steps), ”somewhat active” group (persistent daily count of steps) and ”active” group (increased daily count of steps) in 18-month follow-up.[9]

The association between higher levels of physical activity and lower BMI has been established in adults [10 11], and there has been some evidence that this association might be most pronounced when physical activity exceeds 150 min/week.[10] There is, however, limited knowledge on simultaneous changes in these two factors. In short-term follow-up (18 months) among overweight 54-year-old Canadians, a trajectory with increasing activity has been associated with a trajectory of greater weight loss.[9] There is yet little knowledge on these two factors over longer follow-up. It is also unknown whether developmental patterns of BMI and physical activity differ by age or by gender.

To address the gap in the literature, the objective of this study was to examine concurrent changes in BMI and physical activity over 16-year follow-up by using a group-based multi-trajectory analysis. While conventional statistics show a trajectory of average change of outcome over time, group-based trajectory modeling can distinguish and describe subpopulations (clusters), which may differ substantially from each other and from the average trajectory seen in the entire population. The aim was also to examine, whether the distinguished trajectories are different for less than 50-year-olds and over 50-year-olds and whether the results are different when the study population is stratified by gender.

METHODS

Study population

Participants were drawn from the Finnish Public Sector (FPS) cohort study, a dynamic cohort with follow-up intervals two to four years initiated from 1998/2000. It consists of employees in the municipal services of 10 Finnish towns and 21 public hospitals, who had a job contract for a minimum of 6 months. In year 2000, the most common occupations of the respondents were registered nurse (23%), teacher (19%), practical nurse (13%) and cleaner (10%). The FPS has been described in more detail elsewhere.[12 13] Data in the current study included responses to five questionnaire surveys administered in 2000-2002, 2004-2005, 2008-2009 and 2016-2017to 2017 (average response rate 70%). The baseline was the response given in 2000-2002 or 2004-2005. Participants who had reported their BMI and physical activity in at least two waves were included in the analysis. The ethics committee of the Hospital District of Helsinki and Uusimaa approved the study (registration number HUS/1210/2016).

Physical activity was assessed with a questionnaire at all survey waves. The respondents were asked to estimate their average weekly hours of leisure-time physical activity/exercise and commuting activity within the previous year. The time spent on activity at each intensity level in hours per week was multiplied by the average energy expenditure of each activity, expressed in metabolic equivalent of task (MET). [14] The MET is a ratio of rate of energy expenditure reflecting the amount of consumed energy compared to resting. One MET unit of 3.5 ml of oxygen per kg per minute corresponds to oxygen consumption when calmly sitting down. Weekly physical activity was expressed as MET-h/week and categorized as low (<14 MET-h/week), moderate (14 to <30 MET-h/week) or high (≥30 MET-h/week) physical activity levels.[15 16] This categorization was chosen since physical activity higher than 14 MET-h/week has been reported to be associated with cardiovascular disease[17] and the activity level of 30 MET-h/week has been shown to be needed for weight management[18]. 14 MET-h/week is

approximately the equivalent of 140 minutes of brisk walking weekly. The definition of physical activity in the survey is presented in supplementary table E1.

The BMI was defined as weight/height^2 (kg/m^2) based on self-reported body weight and height. The interpretation of the mean level of BMI trajectories was based on the following categorization: normal weight (<25 kg/m^2), overweight (25 to 29.9 kg/m^2), obese (30-34.9 kg/m^2) and severely obese (≥35 kg/m^2). Of the respondents, only 934 (1%) had BMI ≤18.5, and thus, for the matter of clarity, BMI <25 was considered "normal". Age was defined in full years. The cohort was divided in two approximately even age groups: <=50 (n=31,797, 48%) and >50 years (n=35,055, 52%).

Statistical analysis

The characteristics of participants were reported as means and standard deviations or as absolute numbers and percentage when appropriate.

Group-based multi-trajectory analysis (GBTA) was used to distinguish different developmental trajectories for physical activity and BMI, both treated as continuous variables. This method is a form of finite mixture modeling for analyzing longitudinal repeated measures data. While conventional statistics show a trajectory of average change of outcome over time, group-based trajectory modeling is able to distinguish and describe subpopulations (clusters) existing within a studied population. A censored (known also as 'regular') normal model of group-based multi-trajectory analysis was used. The goodness of model fit was judged by running the procedure several times with a number of trajectory clusters starting from one up to five, until the smallest group was below the pre-agreed cut-off at ≥5%. The Bayesian Information Criterion (BIC), Akaike information criterion (AIC) and average posterior probability (APP) were used as criteria to confirm the goodness of fit. A cubic regression was applied. The trajectory analysis was conducted on two age-groups ≤50 and >50 years as previous studies have suggested that changes in BMI and physical activity may vary depending on the age [19 20]. The sensitivity analysis was conducted by dividing both age groups by gender. No adjustments for co-variables were made.

All the analyses were performed using Stata/IC Statistical Software: Release 16. College Station (StataCorp LP, TX, USA). The additional Stata module 'traj' was required to conduct group-based trajectory analysis. The module is freely available for both SAS® and Stata software (Jones and Nagin 1999; 2013).

Patient and public involvement

Participants of research were not involved in setting the study question and outcome measures and were not involved in the design and implementation of the study or writing the manuscript.

RESULTS

During the 16-year follow-up, the 66,852 participants had reported body weight and height on average in 3.5 (SD 1.3) study waves and physical activity in 3.6 (SD 1.3) study waves. The sample was predominated by 53,468 women (80%). In the younger group (≤ 50-year-olds) mean age was 39.8 (SD 7.2), BMI at baseline was 24.6 (SD 4.0) kg/m^2 and average physical activity was 28.8. (SD 25.5) MET-h/week. In the older group (>50-year-olds), age was 55.0 (SD 2.9), BMI 25.6 (SD 4.2) kg/m^2 and physical activity 26.7 (SD 24.1) MET-h/week.

A four-trajectory model was chosen as the five-trajectory model had resulted in a smallest group below a pre-agreed cut-off of 5% (Table 1). Four concurrent trajectories of BMI and physical activity were identified for both age groups (Figure 1 and Figure 2):

1. Group 1 (38% among ≤ 50 years, 32% among > 50 years): Individuals with normal weight (BMI <25 kg/m^2) and high level of physical activity (30-35 MET-h/week).
2. Group 2 (39% among ≤ 50 years, 42% among > 50 years): Individuals with overweight (BMI 25 to 30 kg/m^2) and moderately high level of physical activity (25-30 MET-h/week).
3. Group 3 (18% among ≤ 50 years, 21% among > 50 years): Individuals with obesity (BMI 30 to 35 kg/m^2) and moderately low level of physical activity (20-25 MET-h/week).
4. Group 4 (5% among ≤ 50 years, 5% among > 50 years): Individuals with severe obesity (BMI >35 kg/m^2) and low level of physical activity (<20 MET-h/week).

Group 1: Individuals with normal weight and high level of physical activity

In this group, the younger respondents demonstrated a stable high level of physical activity with a slight rise towards the end of follow-up and their BMI increased slightly throughout the follow-up. For the older respondents, the level of physical activity decreased markedly during the follow-up, even if there was a slight rising pattern in the middle of follow-up. At the same time, the trajectory of BMI remained flat.

Group 2: Individuals with overweight and moderately high level of physical activity

In this group, the level of physical activity declined in both age groups, but the decline was steeper among the older respondents. In younger respondents, the decrease of physical activity slowed down slightly towards the end of follow-up. Simultaneously, BMI was steadily growing among younger respondents, while remaining relatively flat in older group.

Group 3: Individuals with obesity and moderately low level of physical activity

The physical activity and BMI trajectories were similar to the trajectories observed in group of overweight individuals with moderately high level of physical activity (group #2), but with a slightly steeper decline in physical activity and steeper increase in BMI.

Group 4: Individuals with severe obesity and low level of physical activity

Also in this group, physical activity decreased and BMI increased. In younger respondents, this development slowed down at the end follow-up for both physical activity and BMI. Instead, in older respondents, the decrease in physical activity accelerated towards the end of follow-up with simultaneous slight decline in BMI.

Sensitivity analysis

Stratifying the respondents by gender in addition to age resulted in similar findings with few exceptions (supplementary figures E1-E4 and supplementary table E2). Among normal weight or overweight respondents, the decline in physical activity was steeper among men compared to women.

DISCUSSION

This prospective cohort study in 66,852 public sector employees followed repeatedly by 4-year intervals investigated trajectories of concurrent changes in BMI and physical activity over 16 years. Four trajectory clusters were identified for both participants aged ≤50 and for those >50 years: 1) individuals with normal weight and high level of physical activity; 2) individuals with overweight and moderately high level of physical activity; 3) individuals with obesity and moderately low level of physical activity; and 4) individuals with severe obesity and low level of physical activity. On average, BMI increased and physical activity decreased during the follow-up. Some trajectories demonstrated, however, distinctive features. Over time, the respondents with normal weight or overweight gained only a little weight while preserved a high or moderately high level of physical activity, even if the intensity of physical activity mildly decreased especially in older respondents. The decrease in physical activity and increase in BMI were steeper among the respondents with obesity or severe obesity, who had moderately low or low level of physical activity already at the start of the follow-up. Among the normal weight or overweight respondents, decline in physical activity was steeper among men compared to women.

The observed age-related weight gain is in line with previous studies [4-6 21], as well as the decline in physical activity [4 22 23]. Previous studies have also shown that an increase in BMI slows down with advancing age, and this was also supported by the present findings – the rise in BMI was steeper in the younger respondents [24 25]. During the follow-up, the decline in physical activity mirrored the increase in BMI. Similar findings have been reported before – several studies conducted among middle-aged adults have observed an association between physical activity and weight gain [10 11 26 27]. This association has been described to be dose-dependent – physically active individuals gain less weight than inactive peers. [11] Current results support this finding, since the increase in BMI was less steep in the more active groups. The amount of activity needed to prevent weight gain has been debated. Some studies have concluded that current activity recommendations are not sufficient enough to prevent weight gain and that there is a need for higher activity to remain in the normally

weighted category [10 11 26]. This is in line with the current findings – only high physical activity was associated with normal weight.

The strengths of the study were long follow-up of 16 years, repeated measurements on physical activity and BMI, and a large sample size. For our knowledge, there are no previous multi-trajectory analyses of the relation between physical activity and BMI conducted in adults.

The study has also some limitations. Physical activity was self-reported and only leisure-time and commuting activity were inquired. Thus, physical activity at work was not considered. The distribution of physical activity intensity was skewed – most of the participants were at least somewhat active, and even in the least active group the mean activity level was approximately 18 MET-h/week, which is approximately the equivalent of three hours of brisk walking weekly. BMI was also based on self-reported weight and height, which may cause recall and information bias, possibly resulting in under-reporting of body weight [28]. Most of the participants had BMI above 25 indicating overweight or obesity (62% in the age group of ≤50 years and 68% in the older), which may reflect the current overweight and obesity pandemic. The cohort included predominantly working-age women employed in public sector. Therefore, the results might not be directly reflected on the entire population, since there might be variation in behavior, for instance among unemployed people or entrepreneurs. Moreover, a public sector often employs people with higher socioeconomic status, who might have more knowledge and financial resources to healthy lifestyle choices compared to manual workers.

The results may be of interest for both clinicians and other stakeholders with respect to informing measures targeting increasing physical activity and controlling weight, especially among middle-aged people. Additionally, the information on the established trajectories may give people more motivation to change their health behavior. Further research may reveal risk factors that affect developmental trajectories seen in this study. Such factors may be, for example, gender, socio-economic status, smoking, alcohol consumption and concurrent health disorders among others.

Conclusions

Changes in BMI and physical activity might be interconnected. The normal weight or overweight respondents gained only a little weight while preserved a high or moderately high level of physical activity. Compared to normal weight trajectories, the decrease of physical activity and increase in BMI were markedly steeper among the obese or severely obese trajectories, who also had moderately low or low level of physical activity. The findings were similar for both age groups. Among the normal weight and overweight trajectories, decline in physical activity was steeper among men compared to women. Since physical inactivity and overweight are both risk factors for many diseases, more research is needed to develop interventions that could simultaneously affect both.

LIST OF ABBREVIATIONS

BMI: Body Mass Index

FPS: Finnish Public Sector cohort study

MET: Metabolic Equivalent of Task

FIGURE LEGENDS

Figure 1. Trajectories of physical activity and body mass index amongst respondents ≤50 years

95% confidence limits are shown as dot-lines. For BMI, very narrow 95% CIs are poorly separable in the figure. Time between responses is approximately four years.

Figure 2. Trajectories of physical activity and body mass index amongst respondents > 50 years

95% confidence limits are shown as dot-lines. For BMI, very narrow 95% CIs are poorly separable in the figure. Time between responses is approximately four years.

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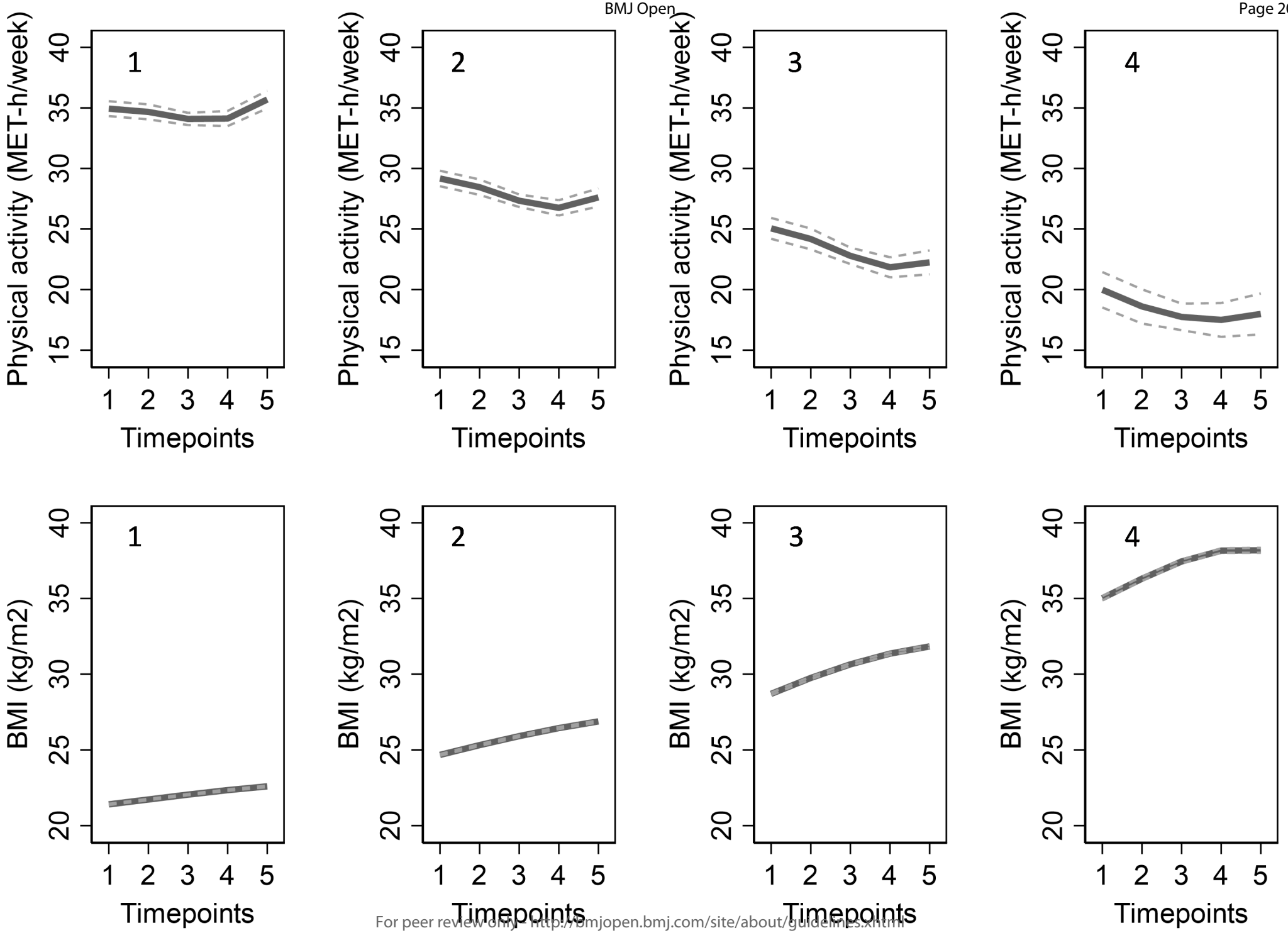
TABLES

Table 1. Goodness of fit of group-based trajectory analysis models. The chosen models are shown in bold.

Model	Smallest group		BIC[1]	AIC[2]	APP[3]
	n	%			
≤50 years					
1-cluster model	31,797	100%	-905,561	-905,509	1
2-cluster model	8,234	26%	-869,531	-869,432	0.94
3-cluster model	3,331	10%	-851,542	-851,397	0.92
4-cluster model	**1,490**	**5%**	**-841,703**	**-841,510**	**0.89**
5-cluster model	898	3%	-835,396	-835,157	0.87
>50 years					
1-cluster model	35,055	100%	-869,200	-869,148	1
2-cluster model	9,690	28%	-836,174	-836,076	0.93
3-cluster model	3,845	11%	-819,600	-819,454	0.91
4-cluster model	**1,888**	**5%**	**-809,601**	**-809,409**	**0.89**
5-cluster model	999	3%	-803,977	-803,738	0.87

[1] BIC = Bayesian Information Criterion, [2] AIC = Akaike information criterion, [3] APP = Smallest average posterior probability


1
2
3
4
Physical activity (MET-h/week)
BMI (kg/m2)
Timepoints
15
20
25
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1
2
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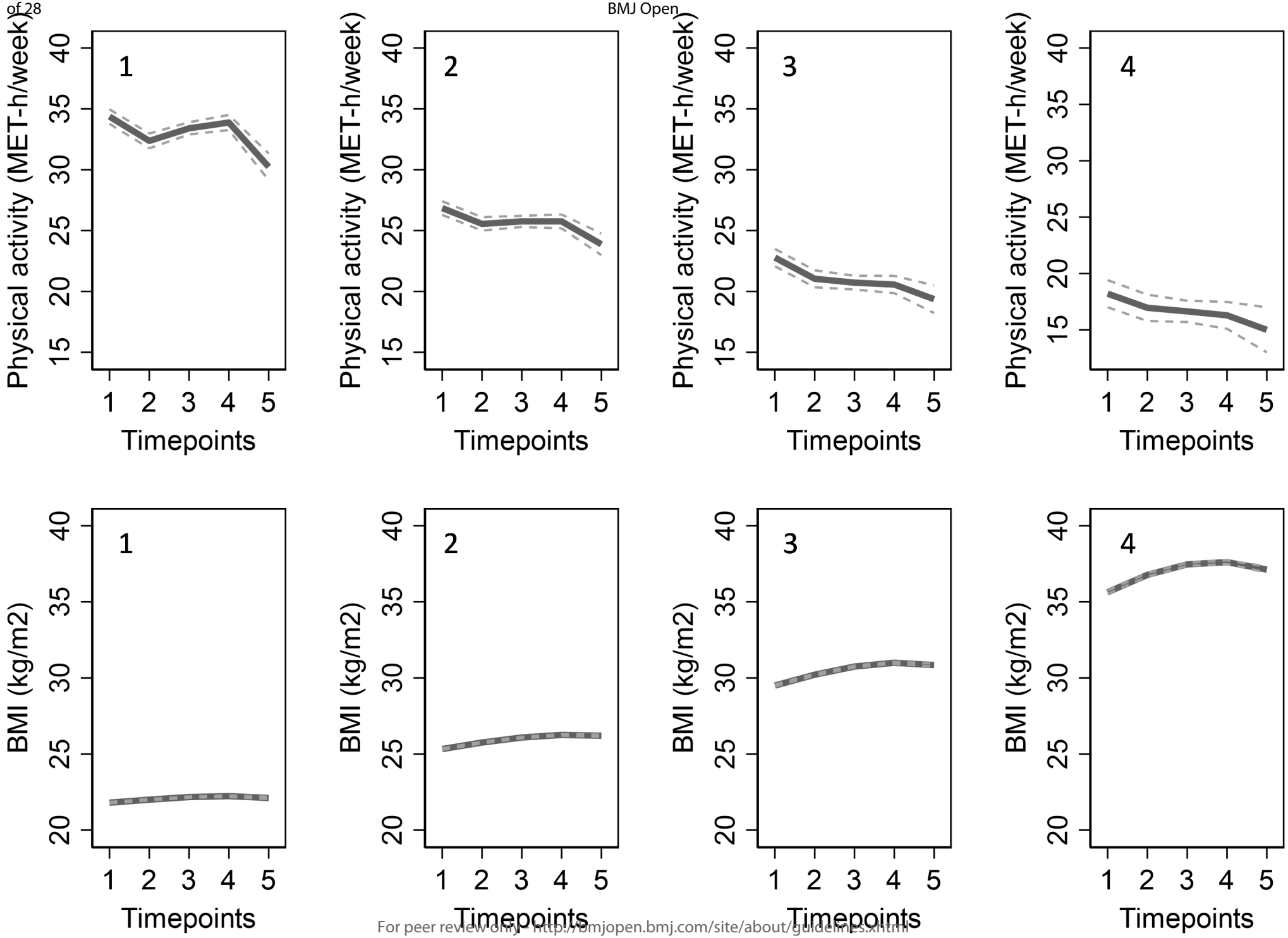
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Physical activity (MET-h/week)
BMI (kg/m2)
Timepoints
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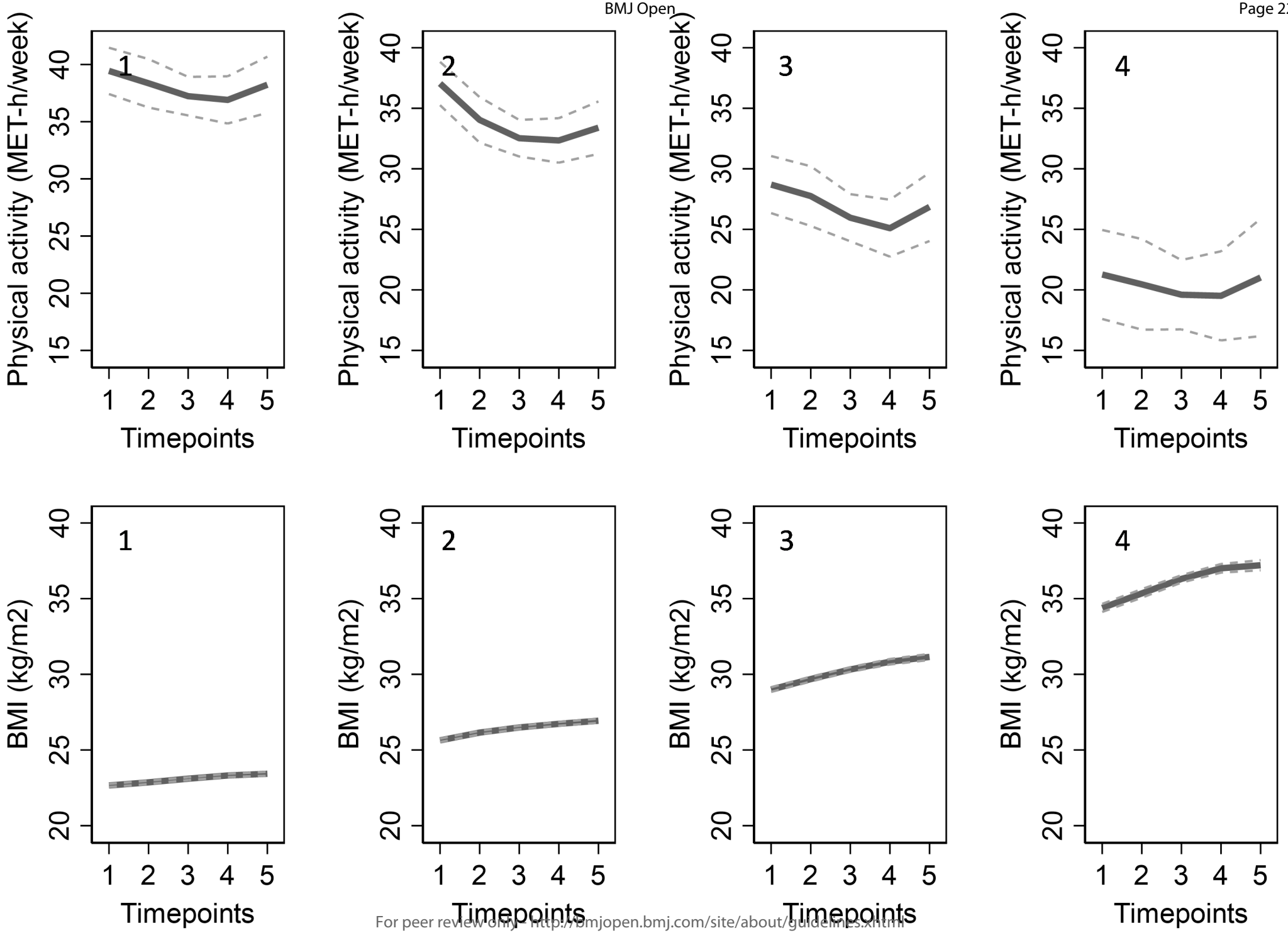

Figure E1. Trajectories of physical activity and body mass index (BMI) amongst men < 50 years
95% confidence limits are shown as dot-lines. For BMI, very narrow 95% CIs are poorly separable in the figure. Time between responses is approximately four years.

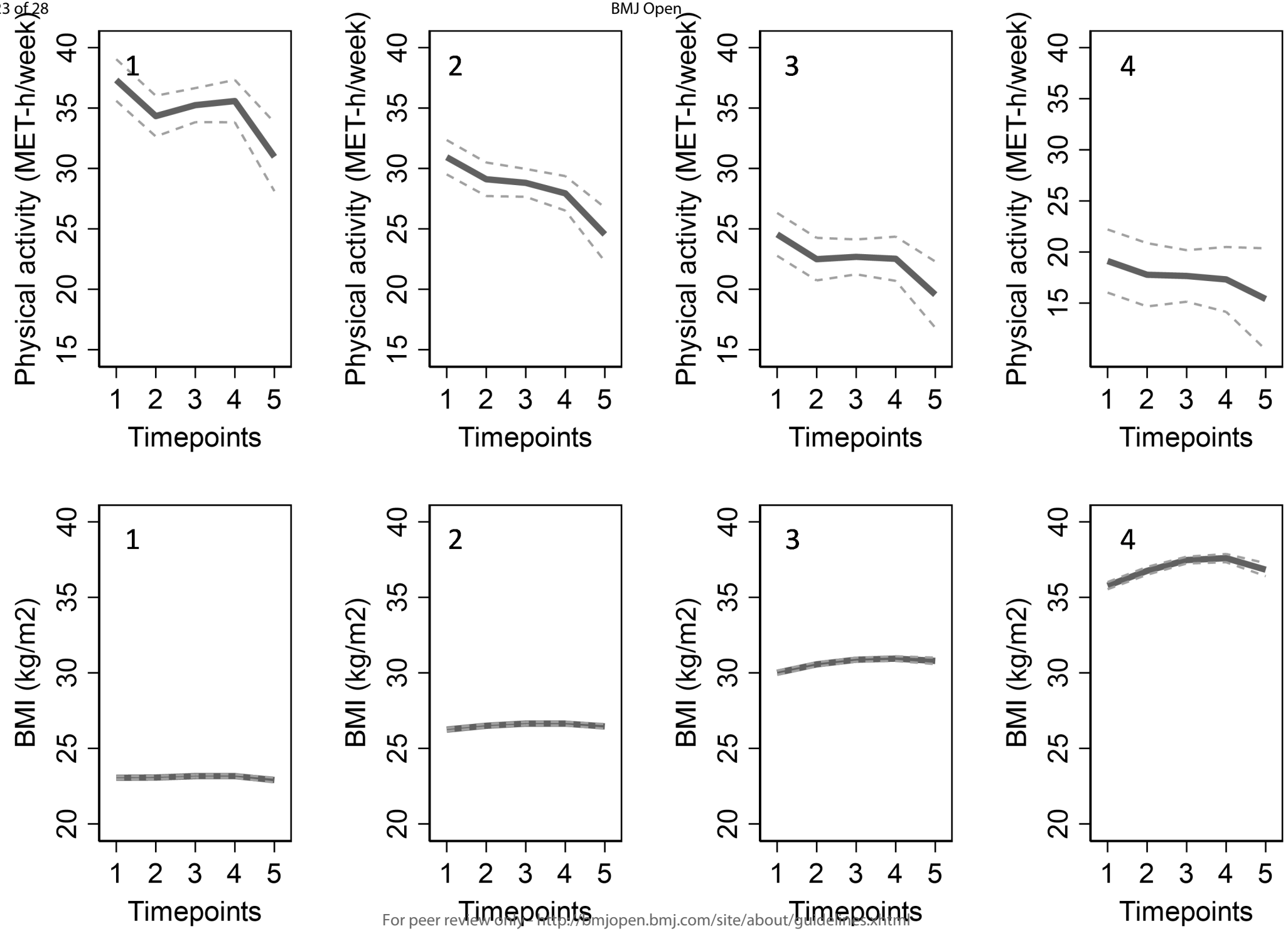

Figure E2. Trajectories of physical activity and body mass index amongst men > 50 years
95% confidence limits are shown as dot-lines. For BMI, very narrow 95% CIs are poorly separable in the figure. Time between responses is approximately four years.

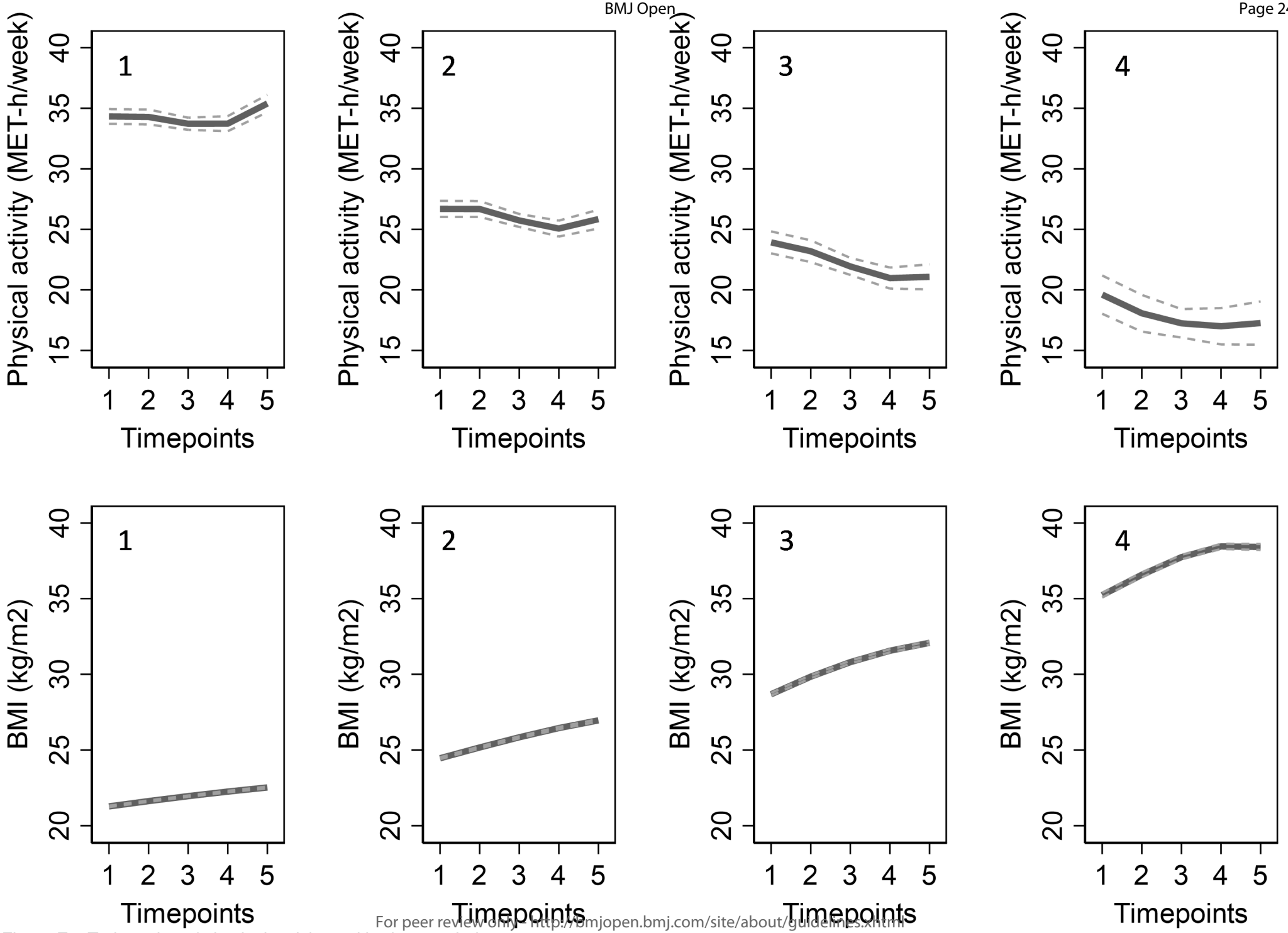

Figure E3. Trajectories of physical activity and body mass index amongst women < 50 years
95% confidence limits are shown as dot-lines. For BMI, very narrow 95% CIs are poorly separable in the figure. Time between responses is approximately four years.

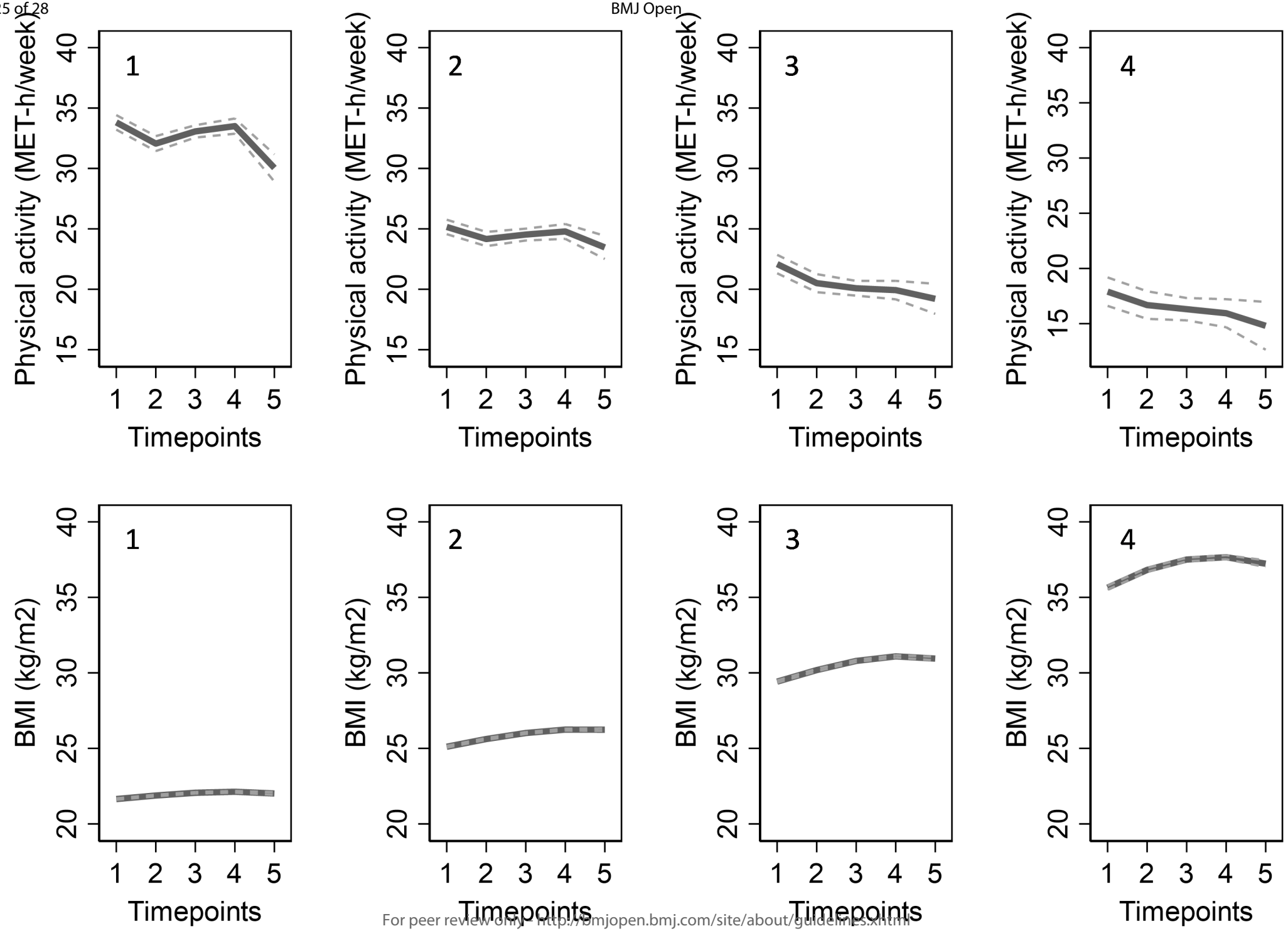

Figure E4. Trajectories of physical activity and body mass index amongst women > 50 years
95% confidence limits are shown as dot-lines. For BMI, very narrow 95% CIs are poorly separable in the figure. Time between responses is approximately four years.

Table E1. Defining the level of physical activity in the survey.

What was the intensity and frequency of your average physical activity (leisure or commuting) during the past year (or since the onset of your disease if the disease had begun less than a year ago)?					
Intensity (Mark all four options)	Amount per week				
	None	<½ hour	1 hour	2 – 3 hours	≥ 4 hours
Normal walking or respective					
Brisk walking or respective					
Light jogging or respective					
Brisk jogging or respective					
The responses were converted into MET units according to a following scheme.					
Intensity (Mark all four options)	MET minutes per week				
	None	<½ hour	1 hour	2 – 3 hours	≥ 4 hours
Normal walking or respective	0	69	138	345	550
Brisk walking or respective	0	99	198	495	792
Light jogging or respective	0	210	420	1050	1680
Brisk jogging or respective	0	240	480	1200	1920

Table E2. Goodness of fit of group-based trajectory analysis models. The chosen models are shown in bold.

Model	Smallest group		BIC[1]	AIC[2]	APP[3]
	n	%			
Men <51 years					
1-cluster	5,894	100%	-156,412	-156,369	1
2-cluster	1,469	25%	-151,020	-150,938	0.93
3-cluster	509	9%	-148,201	-148,080	0.91
4-cluster	**292**	**5%**	**-146,715**	**-146,555**	**0.88**
5-cluster	147	2%	-145,799	-145,600	0.86
Men >50 years					
1-cluster	7,490	100%	-177,574	-177,530	1
2-cluster	1,894	25%	-171,451	-171,368	0.92
3-cluster	622	8%	-168,332	-168,209	0.90
4-cluster	**334**	**4%**	**-166,442**	**-166,280**	**0.88**
5-cluster	174	2%	-165,267	-165,066	0.87
Women <51 years					
1-cluster	25,903	100%	-746,837	-746,786	1
2-cluster	6,530	25%	-715,572	-715,475	0.95
3-cluster	2,773	11%	-700,393	-700,250	0.92
4-cluster	**1,173**	**5%**	**-692,029**	**-691,840**	**0.90**
5-cluster	745	3%	-686,684	-686,449	0.87
Women >50 years					
1-cluster	27,565	100%	-690,012	-689,961	1
2-cluster	7,608	28%	-662,602	-662,506	0.94
3-cluster	3,164	11%	-649,085	-648,944	0.91
4-cluster	**1,536**	**6%**	**-641,136**	**-640,949**	**0.89**
5-cluster	842	3%	-636,666	-636,433	0.86

[1] BIC = Bayesian Information Criterion, [2] AIC = Akaike information criterion, [3] APP = Smallest average posterior probability

STROBE Statement—Checklist of items that should be included in reports of ***cohort studies***

	Item No	Recommendation	Page No
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	4
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	6,7
Objectives	3	State specific objectives, including any prespecified hypotheses	7
Methods			
Study design	4	Present key elements of study design early in the paper	8
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	8
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up	8
		(*b*) For matched studies, give matching criteria and number of exposed and unexposed	
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	8
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	8
Bias	9	Describe any efforts to address potential sources of bias	9
Study size	10	Explain how the study size was arrived at	8
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	9
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	9
		(*b*) Describe any methods used to examine subgroups and interactions	9
		(*c*) Explain how missing data were addressed	9
		(*d*) If applicable, explain how loss to follow-up was addressed	
		(*e*) Describe any sensitivity analyses	9
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	10
		(b) Give reasons for non-participation at each stage	
		(c) Consider use of a flow diagram	
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	10
		(b) Indicate number of participants with missing data for each variable of interest	
		(c) Summarise follow-up time (eg, average and total amount)	
Outcome data	15*	Report numbers of outcome events or summary measures over time	10,11

Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included (*b*) Report category boundaries when continuous variables were categorized (*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	10,11
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	10,11
Discussion			
Key results	18	Summarise key results with reference to study objectives	12
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	13
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	12,13
Generalisability	21	Discuss the generalisability (external validity) of the study results	13
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	2

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at http://www.strobe-statement.org.